CHEMICAL WORKS

THEIR DESIGN, ERECTION, AND EQUIPMENT

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PREFACE

In placing the present work in the hands of chemical manufacturers, chemical engineers, and works chemists, the object of the authors has not been to add to the treatises on chemical engineering which are already in existence. They have simply attempted to condense into a series of monographs the fruits of some twenty years' experience of the actual designing of chemical works and the selection of chemical plant, supplementing the letterpress with a series of actual working drawings such as have not hitherto been presented in a volume of this nature

In works of the customary type dealing with chemical engineering, complete working drawings, such as will be found in these pages, are very infrequent. The authors of theoretical handbooks on this subject have dealt at length with the theory of design, but they seldom provide the manufacturer or works manager with such drawings as will assist him in the designing of a new works or the remodelling of an old one. The reason for this omission is, of course, obvious. Some attempt has been made by the authors of the present volume to remedy this omission. The drawings included in the earlier sections embody the result of actual experience in planning chemical works. The authors make no claim to finality in presenting the various arrangements suggested, but the manufacturer or engineer who studies the drawings is simply assured that the practice which

is therein indicated has been followed with a large measure of success in existing works both at home and abroad.

Commencing with some consideration of the important question of the selecting of a site for a new works, practical hints are given as to the laying out of the land, the utilization to the best advantage of the various levels which are generally to be found, and the provision of such important adjuncts as railway sidings, etc. The question of foundations is dealt with and the best arrangement of the drainage is indicated. A few notes on materials used in construction are next considered, and, following this, the first principles to be observed in the actual laying out of a works are dealt with. Questions of transport by rail or water call for attention, and the making of roads for internal communication between the different sections of a large works is not lost sight of. The design and erection of the various buildings need to be carefully considered, and here some useful hints as to the best arrangements to secure a proper sequence of operations will be found. As the volume is intended to be equally useful to the management of large manufacturing establishments as to smaller concerns, it will be found that questions such as the planning of the various artisans' shops and stores find a place in this section of the book. Some notice of the arrangements for fire-prevention, and the organization of works fire brigades, will be found of interest, while hints on ambulance arrangements and provision for dealing with the accidents inevitable in all large works are also given.

Having dealt with the guiding principles which should be followed in the selection of the site, the materials used, and the best practice in planning a works, a chapter is devoted to the important subject of power

plant. A modern power-house is described, and although this may be regarded as somewhat of an ideal arrangement, the principles which are laid down are those which are now observed in the most up-to-date works, and the manufacturer who operates on a modest scale will not fail to secure some useful hints from a summary of the best practice in the generation and application of power.

Subsequent chapters deal with that class of chemical plant into which constructional engineering enters very largely, and here again it will be found that much information not usually given in books of this description has been included. The special types of buildings suitable for the housing of chemical plant have been dealt with in a practical manner. This section of the book has been chiefly devoted to detailed descriptions of sulphuric acid plant, nitric acid plant, hydrochloric acid plant, artificial manure plant, and sulphate of ammonia plant. The working drawings which are incorporated in this section represent actual designs worked out in the light of a long experience of the conditions of manufacture which obtain in this country. Each section dealing with a specific type of plant has been so modelled as to include the design of buildings most suitable for the housing of engines, tanks, etc. (where buildings are necessary). This method of treatment results in a series of chapters each of which deals with a particular department of chemical plant, and the value of this arrangement lies in the fact that the works manager who is confronted with the task of designing such a plant has placed before him a reliable guide, especially to the constructional side of the work.

The third section of the volume is devoted mainly to a consideration of the general plant which is required in the equipment of a chemical works. The selection here

has been carefully made, and includes only the best and most up-to-date apparatus. Here, again, the fruits of a lengthy experience have been brought to bear, and the plant described and illustrated will be found to be the best of its type. As far as possible, the "catalogue" element has been eliminated from this section. This is not an easy thing to do. All manufacturers have access to engineers' catalogues, and the task which confronted the authors was to select those pieces of plant of which they have practical knowledge, and to give such details as are not readily accessible to the average manufacturer or works chemist, and to furnish them with such hints, drawn from actual experience, as will enable them to make a wise selection. Progress in this department of engineering has been very rapid of recent years, and nowhere is care more needed than in securing well-designed and durable accessories for the equipment of a chemical works.

To sum up the objects which the authors have in view in placing this volume in the hands of the technical chemist, their aim has been to present in each chapter a summary of sound practice in up-to-date construction; to give such practical details as are not generally to be found in the theoretical treatises on the subject; and to aid those responsible for the management of chemical works in the task of designing new works by dealing with the subject as it would be dealt with by a consulting chemical engineer if such an expert were called in to advise. The most valuable portion of the book will probably be found in the plates of working drawings which are presented, and the chapters dealing with the design and arrangement of the plant. In the nature of things it is not possible to include details of what are still semi-secret pieces of chemical plant. It is equally impossible to give elaborate descriptions of some types

of plant which are still in the process of evolution; but within the limits which the authors have carefully imposed upon themselves the volume will, they believe, be found a useful addition to the literature of chemical technology.

S. S. D.
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DOVER, *July*, 1911.

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CHAPTER I.

CHOICE OF SITE.

One of the chief features governing the choice of a site for a works, apart from its vicinity to canal, railway, or river approach for the means of carriage of its raw materials and finished products, is, of course, the nature of the ground itself, considered as to its suitability for carrying the structures required for the operations of the particular manufacturing processes in question.

A good natural foundation should, if possible, be secured. By this is meant either a good rock foundation, close gravel, or hard clay. Ground which is of a shifting nature should be specially avoided, as also ground which would require pile-driving, and these remarks are specially applicable where any heavy superstructure is contemplated.

For this reason trial holes should be dug in various parts of the site, and a site plan prepared on which the position of the holes can be marked, together with notes on the nature of the soil at these points. If the site is not level, the levels could also be plotted and marked on this plan, although a separate plan giving the levels is more often preferred.

For choice, a level ground is preferable in many cases, although in some instances advantage may be taken of inequalities, especially in works designed for the heavy chemical trade, or in alkali works. Several instances might be cited where, in the experience of the authors, varying levels have been turned to account by using the lower levels as dumping-pits for the large quantities of waste of different kinds made during the processes of manufacture. Again, similar advantage may be taken of varying levels where liquids may be allowed to find their way from one process to another by gravity, instead of being pumped, thus effecting a saving in cost.

It is hardly necessary to draw the attention of those engaged in the alkali and heavy chemical trade on a large scale to the necessity for choosing a site where plenty of land is available, as a considerable area is taken up by the large stores of raw material required both for use in process operations and for repairs to plant and buildings.

In some districts where very few houses exist, it may be necessary to build cottages for the employees, and additional ground may be purchased near to or adjoining the works for this purpose. Port Sunlight (Messrs Lever Bros.) is a fine example of this kind, but not many firms could face the expense of putting up cottages of this type A less pretentious scheme is that of the village of Kynocktown, in Essex, erected for the employees engaged in the explosives factory of Messrs. Kynock, Limited. Although not engaged in the chemical trade, while considering this subject the arrangements which Messrs. Cadbury, of cocoa fame, have made for their workpeople at Bournville, near Birmingham, are worthy of careful study.

As far as possible, it is also well to take into account probable extensions to the various buildings and plant and the ground that would be required for this purpose, and while aiming to arrange the plant so as to render it as compact as possible, the general lay-out should be carefully considered, so as to permit of future extensions. Port Sunlight may again be taken as an example of a site chosen which admitted of ready expansion, as evidenced from the fact that from a weekly output of about 800 tons per week when the works were started there, some twenty years ago, the weekly output is now over 3000 tons, and employment is given to some 4000 people, while extensions are still going on Many operations that were probably not thought of in the original scheme of these works when they were transferred to Port Sunlight, have been capable of being installed. It is stated that over sixty trades are to be found carried on at Port Sunlight. We venture to think this could not have been done had not Messrs. Lever Bros. wisely chosen their site with a view to expansion.

This point sometimes receives little consideration. Although such provision involves additional expenditure upon land, it will in many cases be found better to face such expenditure, especially if the manufacturing operations are to be upon a

large scale. Even in the case of a comparatively small works, expansion is far easier and cheaper if a little spare land can be secured at the outset. It is often a simple matter in planning a works to allow space for duplication of the most important sections of the plant. It may be unnecessary, for instance, to double the minimum amount of land required and thus at the same time double the minimum capital expenditure on land, as it will be found that to make provision for additional units of the more bulky plant will be sufficient. If a power house, for instance, is to be erected, the space required for an additional steam or gas engine does not mean that a plot of land double the size of that required for a single engine will be called for. Similarly, in designing the boiler-house it is not necessary to allow for actually doubling the number of boilers, but if, say, three or four are required at the outset in a works of medium size, then provision for two additional boilers would enable the manufacturer to add very appreciably to the capacity of his plant at a small additional cost for land. Moreover, spare ground is always extremely valuable for storage purposes. The point to be kept in mind is that if a works is even moderately successful, then expansion in some degree will be necessary at a fairly early date, and one of the greatest drawbacks to such expansion is lack of space.

Where land is chosen in the vicinity of the coast, or alongside an estuary, it is advisable to obtain definite information as to the highest tides with respect to the levels of the site chosen, as these will affect, to a great extent, the arrangement of the drainage, which is a feature that is too frequently lost sight of in the laying out of a works. We have known cases where insufficient attention to the details of the drainage scheme has led to a vast amount of expense and inconvenience at a later date. Buildings have actually been placed over the main drains, and much expense has been incurred in obtaining access to these drains when a stoppage occurs. We shall have more to say on this matter when dealing with the laying out of the works in Chapter III.

When the site has been selected, and the general arrangement of buildings and roadways has been settled, the question of drainage should then be the first point to receive close atten-

tion. If the site is on the coast or on a tidal river, the flues from chimneys, boilers, and furnaces should be kept above tide or flood level, as the stoppage of any industrial process might easily be caused by the flues being flooded. We may quote one example, where, owing to this matter being overlooked, the pit of a set of gas-producers was placed below the level reached by high water at spring tides. The whole of the producers were put out, and the furnaces which were supplied with gas from them rendered useless for the time being. If for any reason a pit has to be below water level it should be built as a concrete tank, and finished off with cement, so that water cannot leak through. The reason for the pit being so low down in the case just mentioned, was in order that the charging stage should be on a level with the floor of the coal wagons, and thus facilitate unloading the fuel.

A plan that was adopted by a chemical works recently erected, situated on a tidal estuary, was to build all the flues on the ground level, and fill up level the top of these with the excavated material from other portions of the works. This placed the working floor level at such a height as to leave the adjoining ground available as a tip for the cinders and clinkers, and other solid refuse, and ensured the flues being well above any drains; all the drains being below the natural ground level.

A plentiful supply of good water is a necessity for most chemical processes. It may happen that the water that is suitable for process operations would not be suitable for use in the boilers, or vice versa.

We have known several cases where on this account wells have been sunk, in addition to the other sources of supply for the works in question. Where a well is sunk, the top or surface water must be prevented from draining into it, so as to avoid impurities. It may be necessary in order to secure this, to use cast-iron cylinders bolted together with internal flanges, a common size for this purpose being about 3 feet diameter and in 6 feet lengths. This is for cases where water can be reached at moderate depths, but where it is necessary to go to a great depth recourse must be had to a bore-hole lined with tubes, the joints of which must be thoroughly tight. But deep bore-holes are costly, and should only be resorted to where other means of supply fail.

At one works with which we were connected, the water supply for the boilers was obtained from a deep bore-hole, and the water was raised by means of an air jet supplied from an air compressor The air lift was kept almost in constant use, and supplied an open reservoir from which a battery of six Lancashire boilers obtained their supply.

In negotiating for the purchase of land it is advisable, if possible, to select a site where the purchase carries with it any mineral rights. This provision frequently guards against any subsequent complications which might otherwise arise. In any case, careful investigation should be made into the question of these rights.

In districts where mining or brine pumping is in process, serious damage to buildings often results from subsidences, and for this reason, if at all possible, such districts should be avoided. In the case of an alkali works, brine springs may of course be bought along with the land, and here the possibility of subsidence is entirely the concern of the manufacturer

Another important question which must be considered is that of the proximity of the projected works to agricultural land. Farmers have, generally speaking, an inveterate hatred of chemical works. In justice to them it must be admitted that they have sometimes ample cause for this ; but it is a fact that in many instances complaints of nuisance arising from chemical works are frequently made on the most flimsy grounds Various particularly evil-smelling industries are tolerated far more readily than the legitimate chemical processes, and the unfortunate manufacturer who happens to select a site where the prevailing winds render it impossible for him to conceal his existence will speedily find himself in serious trouble with any local magnate whose residence is within range of the works. It is useless to plead that in connection with chemical manufacturing establishments some degree of odour is inevitable. Even where actual damage to growing crops or vegetation cannot be proved, the management are very seriously handicapped, and this aspect of affairs must be given ample weight when searching for the best site.

The direction of the prevailing winds may easily be ascertained if there are any trees in the neighbourhood, and this, as emphasized above, is a matter which is well worthy of close attention.

The geographical position of a chemical works has a very important bearing on the commercial success of such an undertaking, and in the selection of the site for a new works the considerations which must be borne in mind are now receiving careful attention The points arising under this head are of equal importance to all manufacturers engaged in any of the allied industries, and a few examples may be usefully mentioned. In the case of an alkali works it is imperative that a plentiful supply of brine shall be available, or, failing this, that the works shall be so situated that chemical salt may be obtained in large quantities with a minimum of expense for carriage. The natural situation of Cheshire has grouped in that county and the adjoining county of Lancashire the principal works in the alkali trade. The Cheshire salt maker has at hand abundant supplies of fuel from the Lancashire coal-fields, and his other principal raw materials, such as pyrites or brimstone, may be brought by water by means of the Weaver Navigation or the Manchester Ship Canal, reducing the cost of railway transport or securing to him the advantages of water competition with the railways.

In the soap trade, we find Messrs. Lever Brothers, as already noted, established at Port Sunlight, where not only can the supply of chemicals be drawn from the greatest alkali district in the world, but fuel supplies are close at hand, and the other bulky raw materials, such as oils and fats, may be brought by ocean-going vessels to the river-side wharves of the factory. There can be no doubt whatever that such natural advantages of geographical situation have contributed very materially to the wonderful prosperity of Port Sunlight.

The same district has recently witnessed the development of a large works in an industry which is in many respects becoming of a chemical nature—we refer to the Hawarden Bridge Iron Works of Messrs. John Summers & Sons, Limited. Here, on the Dee marshes, smelting furnaces and rolling mills on a very large scale are supplemented by a large chemical works which produces the vitriol, hydrochloric acid, etc., used in the production of galvanized iron, dealing also with the residual liquors resulting from the galvanizing process. In such operations considerable land is required for such bulky plant as vitriol chambers and crystallizing vats. Other advantages of such a situation are found in the easy disposal of effluents, as well as

the cheap water transport of very heavy goods—both raw materials and finished products. Iron ore can be brought in bulk cargoes, salt and pyrites come in the same way, while export business is very much simplified

Another favoured district for such works as come within the scope of the present volume is that which is served by the Manchester Ship Canal, and here, as an instance, may be cited the great Westinghouse Works at Trafford Park, Manchester. The Co-operative Wholesale Society has a large soap works at Irlam, also on the Manchester Ship Canal, while Messrs. Crosfield & Sons, at Warrington, benefit in no small measure by the facilities for water transport derived from the same great waterway.

Other districts might be mentioned as showing the importance of careful selection of the site for a new works, but sufficient has been said to emphasize the necessity of careful attention to some of those points which make for economy of production and cheapness of transport. Such districts as have been referred to combine nearness to salt supplies, close proximity to large coal-fields, water carriage by sea, river, and canal, with efficient railway facilities.

Another important point in the selection of site is that it shall be within easy reach, by road, of the market which it is intended to tap. From the point of view of cheap transport the increasing adoption of the motor wagon renders it necessary to be on the line of good highway communication. Recent developments in the railway world have made it imperative that the manufacturer shall have an alternative system of inland transport with which to compete against the high freightage charges of the railway companies. Second only to water carriage must be placed an efficient system of motor transport for goods. This is a subject which is receiving close attention on the part of many manufacturers.

In deciding upon the locality of a new works, consideration must be paid to the facilities afforded not only for the transport of raw materials and finished products, but also to such points as the sources of supply of electric current for power and lighting, and cheap gas for power generation. Various districts are now being brought to the notice of manufacturers who may be contemplating the establishment of new works, by municipalities which offer special treatment in these directions. The

steady increase in the rates of many large towns has compelled large firms to migrate, and where such a change may be decided upon it is needless to emphasize the advantage of cheap supplies of electric current and gas. In some departments of the chemical trade, and particularly in connection with any process of an electro-chemical nature, the possibility of obtaining cheap electric current from the local generating station is very important. It is to the advantage of a municipal electricity works to secure a full "load" during the day-time, when the current is not being required for town lighting, and in some districts, at all events, it will be found that current for industrial use may be obtained from the town's main at a lower figure than that at which it could be generated in the works itself. To produce electric current by means of steam-power is generally an expensive process. Present-day practice points to the use of large gas engines as being the most economical source of mechanical power, and if gas engines are adopted, the choice of supply of the necessary power-gas lies between the town's supply and the adoption of gas-producer plant. Where gas for power purposes is available at a low figure, this may obviate the necessity for installing plant for its manufacture, and in some towns in the North of England, very low rates are offered for gas supplies. The adoption of producer-gas, to be transformed into power by means of the gas engine, places in the hands of the manufacturer a very cheap method of generating electric current in his own works. The subject of power generation will be found dealt with at length in the chapter on this subject, but in passing it may be observed that the facilities offered in the direction of cheap electric current and cheap gas may with advantage be carefully weighed when deciding on the site for a new works

The control of chemical works by the Local Government Board under the Alkali, etc., Works Regulation Act, as regards the emission of noxious vapours, has now been in force so long that the relations between manufacturers and the authorities are clearly defined. The administration of this Act had been carried out very wisely, and with marked benefit to the manufacturers themselves Such a result has been attained by entrusting the inspection of chemical works to men who have had long and practical experience in the working of the various

processes, and in touching upon the subject of gaseous effluents it is only fair to record the cordiality of the relations between the inspectors and the firms engaged in chemical manufacture. For convenience of reference, the text of the New Alkali Act, which consolidated the previous statutes, is given as an appendix to the present volume.

Of equal importance with that of gaseous effluents is the question of the disposal of waste liquors from chemical processes. Here, again, the wisdom of selecting a site where such effluents may after suitable treatment be turned into adjacent water-courses is self-evident, and this brings up the question of the supervision exercised by River Boards over such watercourses, and due weight must be given to the requirements of the various authorities.

In some cases the River Conservancy Boards permit effluents containing not more than a small percentage of acidity, and where effluents of an acid nature are likely to be turned from the works into the stream or sewer, some process for neutralizing, similar to that which is in vogue in many works, namely, liming the ditches, would have to be adopted.

Where liming is resorted to, the lime should be added to the effluent in the form of milk of lime, and a good mixer, of which there are several on the market, should be used. It should be borne in mind that it is far cheaper to buy good lime that is readily solvent, even at a higher price, than a cheap lime which leaves a large amount of sludge. The works chemist should make tests of the effluents twice or three times a day and a record should be kept of these. On the visit of the River Conservancy Board inspector samples should be taken at the same time that he takes his samples for analysis.

If the levels would allow the flow of the effluents to fall over a cascade, this would greatly add to the mixing of the effluent with the milk of lime. Otherwise it is a good thing for one of the labourers to be told off to stir the ditch up with a paddle occasionally

So far we have been considering the choice of site in relation to works of some magnitude, but there are of course many minor chemical industries in which no obnoxious gases are evolved or effluents to be disposed of, and which would be quite capable of being carried on in a manufacturing town without

giving cause for any complaint to such manufacturers. It might here be possible to take advantage of the particular districts where corporations are laying themselves out to supply electrical power, hydraulic power, and gas supplies, both for power and lighting.

CHAPTER II.

NOTES ON MATERIALS USED IN CONSTRUCTION.

IN considering the materials of construction mostly used in connection with chemical works, these may for convenience be placed in four classes: building materials, such as bricks, slate, glass, stone, cement and concrete-forming materials, fire-clay, earthenware, and similar substances comprise one class; timber may form another class; metals still another; while in a fourth class such miscellaneous substances as rubber, leather, felt, etc., may be placed.

METALS.

In the alkali trade, lead takes the foremost position amongst this class of materials. Cast-iron comes a good second, with steel and wrought-iron following. Such materials as copper and alloys with copper, zinc, aluminium, platinum, phosphor-bronze, and regulus metal are only used in a minor degree compared with the metals previously mentioned.

Lead.—The lead used for chemical purposes is specially pure The weight of lead, roughly speaking, is about eleven times that of water. Sheets of lead can now be rolled to almost any thickness required, and for sheets of medium thickness can be obtained up to 9 feet in width and up to 25 feet in length, or more. Lead has a greater co-efficient of elongation under heat than any other metal, and, being extremely ductile, is capable of being beaten into almost any shape desired. It must be remembered in dealing with lead-work for chemical purposes that no soldering is permissible, and that all joints must be made by melting, or, as it is generally termed, lead-burning. This subject is touched upon in Chapter III, in speaking of the plumber's shop.

Lead barreling can be obtained in 12-feet lengths, from $2\frac{1}{2}$ inches to 6 inches in diameter, and solid drawn-lead pipe of the smaller diameters can be obtained in coils of almost any length desired.

Old chemical lead will generally fetch a fairly good price when it is disposed of, but in most cases it can be utilized by melting up for various purposes in the factory. Lead is generally spoken of according to the weight per superficial foot, such as 5-, 6-, 7-, or 8-pound lead.

In conjunction with leadwork generally, attention may be drawn to the numerous fittings that are made in regulus metal, and which can be readily connected by the plumber to vessels of lead. These fittings are well known to all chemical manufacturers and chemical engineers.

Sulphuric and hydrochloric acids have no action on lead at ordinary temperatures, and but little action at a boiling temperature. Nitric acid dissolves the metal with evolution of nitric oxide, especially when the acid is rather dilute. The vapours of acetic acid corrode lead rapidly, and in the presence of carbonic acid convert it into white lead. Alkalies have no decided action. Chlorine converts the metal slowly into lead chloride, but the surface film thus formed protects the metal beneath.

Lead is extensively used as a jointing material in forming spigot and faucet joints where the liquid lead is run in. A form of lead joint which is said to stand heavy pressure, and which is claimed to be made more easily than a run-lead joint, is that made with lead wool as manufactured by the Lead Wool Co., of Snodland, Kent.

Copper.—Copper, although not used to the same extent in chemical works as lead, is employed extensively in condensing and evaporating plant for various purposes, while its uses in connection with electrical plant are too well known to mention in detail.

Phosphor Bronze.—In a paper entitled "Some Notes on Phosphor-Bronze," read before the Institute of Metals, Mr. Phillips pointed out that the special characteristics of this alloy are: (1) its freedom from corrosion by salt water, which is apparently largely due to the absence of zinc; (2) its high qualities as a mechanical constructive material as compared with an ordinary zinc-free brass; (3) the small effect which rise of temperature has upon its mechanical properties, which remain practically unimpaired at temperatures at which zinc-containing copper alloys exhibit serious falls in strength; (4) a spark cannot be readily obtained from it by a blow, (5) phosphor-bronze of

high phosphorus content possesses low friction co-efficients for most metals, and is hard enough to resist abrasion well On account of these properties phosphor-bronze is particularly suited for boiler fittings and fittings exposed to water, for the construction of machinery for the manufacture of explosives, and for bearings for high-speed machinery.

Aluminium —In a paper also read before the Institute of Metals, Mr Bonner has called attention to the fact that aluminium is now selling at about half the price which it commanded seven years ago. The metal, owing to its lightness, is very useful where handling of liquids has to be performed by means of movable troughs, more particularly in cases where troughs or similar vessels in lead would be extremely heavy and unwieldy, whereas such vessels in aluminium can be readily handled. We have used aluminium fans for removing acid fumes, and have found the metal to withstand the action of the acid much better than any other material at similar cost. In explosives works particularly various articles of aluminium are in use. The only drawback in the utilization of the metal for general purposes is the difficulty of brazing, as this requires an expert knowledge to make successful joints

In a paper read before the Iron and Steel Institute Mr. F. J. R. Carulla has given some useful hints on the use of cast-iron in the construction of chemical plant. He observes that cast-iron is a substance which, in consequence of its varied composition and uncertain properties, it is most difficult to classify. The consequence is that there are certain firms who possess experience and special knowledge of the use of particular brands for various purposes that are unknown to the trade in general; nevertheless some simple rules can be applied even in this case.

For certain purposes, as, for example, ammonia stills, cast-iron seems practically everlasting, and there can be no secret as to brands. The cast-iron parts of such an apparatus known to the writer of the paper were stated to be practically perfect after eighteen years of working. There was no sign of wear in any of the cylinders, and a remarkable fact was that the lower section of the liming cylinders, containing the manhole, had been repaired at the time of erection, a large blowhole being detected in the casting; the place was made good with rust

cement (iron filings and sal-ammoniac), and notwithstanding that the work was carried on at a pressure of eight to ten pounds per square inch, no leakage had taken place.

In the case of ammonia stills, the reactions are entirely basic, lime being used to drive off the fixed ammonia, but even acid chemicals have sometimes little action on cast-iron. Nitre pots of cast-iron will withstand the action of sulphuric and nitrous acids in a glowing furnace remarkably well, the seething mass taking months and sometimes years to destroy the vessel. Yet when hydrochloric acid is in question, cast-iron succumbs like any weaker metal. Whilst this is common knowledge, the fact is not realized to its full extent. Percy ("Iron and Steel," pp. 145-47) describes the experiments of Daniell, who obtained from a cube of cast-iron, immersed in dilute hydrochloric acid, a spongy mass, easily cut with a knife, which was dark grey, and somewhat resembling plumbago. He also gives the following analysis, by Calvert, of such a residue produced by the uninterrupted action of the acid during two years on cubes of the metal.—

	Cast iron. Per Cent	Residue Per Cent
Carbon	2 900	11·020
Nitrogen	0 790	2·590
Silicon	0 478	6 070
Iron	95·413	79 960
Sulphur	0 179	0 096
Phosphorus	0·132	0·059
Loss	0 108	0·205
	100·000	100 000

As an example of the violent and rapid manner in which corrosive action may take place, Carulla instances a case in which the plug of a cast-iron cock, used to keep back ferrous liquor containing a very small percentage of hydrochloric acid, was acted upon to the depth of one-eighth of an inch in a few months. This discovery was most opportune, as it caused the examination of a cast-iron vessel of considerable size into which the liquor in question was admitted, and a similar action was found to be going on It was fortunate that this was perceived at such an early stage; as little damage had been done, by a variation in the process, in no way detrimental, the action was arrested while the vessel was still good. Ammonia had to

be used in the process, and a portion being introduced at an earlier stage, the acidity of the liquor was neutralized.

It is therefore evident that the action of hydrochloric acid must be carefully guarded against. Both the user and the maker of vessels that have to withstand it are interested in the matter, and here comes in a distinction. Cast-iron is divided into two main groups—the white and the grey. The experiments of Professor Daniell showed that grey iron is more rapidly attacked than the white—three times as fast. Hence, if a cast-iron vessel is required to resist the action of hydrochloric acid, it is reasonable to say that white iron should be selected. Other conditions may require consideration, however, and if the vessel has to resist internal pressure, the tougher grey iron is preferable to the white and brittle. The natural solution of the problem is to make a mixture of a white and a grey brand, the grey giving the tenacity and the white the acid-resisting power. Mr. Carulla suggests that a better plan, however, would be to cast round collapsible chills with grey iron, when the interior of the casting, assuming this to be cylindrical, becoming white iron to a certain depth, would offer the required chemical resistance, whilst the outer coat, of considerable thickness, remaining grey, would give the necessary tenacity. Vessels for chemical operations could certainly be produced on this plan if it has not already been adopted.

In connection with the action of hydrochloric acid there are operations in which not only the unexpected but the unsuspected may happen. It is well known that hydrochloric acid, in its free state, and especially in its weak state, must be guarded against, but the action of chlorides is apt to be overlooked. When ammonium chloride is heated to 300° C. it is dissociated, the hydrochloric acid being set free, with serious results in the case of iron tar stills, for example, which when heated to 325° C. are affected by the ammonium chloride that has not been separated from the raw tar.

A further point emphasized by Carulla is that wrought-iron chaplets should not be used to hold up the cores of pipes, etc., intended for chemical work. Failures are certain in such cases when the chemical has any action on iron, as the comparatively pure metal is more readily attacked than the cast-iron. Even when cast-iron supports are used failures may still result, as the

fusing together with the main casting may not be complete. The method of casting pipes vertically without the use of chaplets is, therefore, to be recommended for chemical work

Miscellaneous—Of miscellaneous materials, the following are much used: Vulcanite, rubber, rubberite, ebonite, asbestos, glass, white lead, leather, Uralite, Willesden paper, hemp and rope packing, and felt.

Asbestos.—Asbestos is a most useful material in chemical works. It is unaffected chemically by many of the active agents likely to attack most insulations; it is generally applied for boiler and pipe coverings to prevent heat radiation, and its efficiency is greatly increased by developing the cellular structure of the covering A mass of asbestos, fiberized and then compressed, is highly porous, and is rendered not only waterproof, but an especially effective insulator, under conditions of varying moisture, by being saturated with certain varieties of asphalt, for example.

There need be no waste with asbestos, as the scraps from a sheet, soaked in water, make a good cement that can be used for making joints in a similar way to making a rust joint, and which will not be affected by acids. When asbestos is used for making joints between flanged pipes, it should be blackleaded on each side, so that if required to break the joint it will leave easily.

In close connection with asbestos in its various forms is *uralite*, a building material made in sheets, and composed of asbestos fibre cemented by a mineral glue. Uralite is manufactured in large sheets, which can be employed in the place of corrugated iron in roofing, and of wood in lining walls which it is desired to render incombustible. It has the advantage of not being affected by water at any temperature, nor by fire, and consequently resists the action of the weather when exposed, as when employed in place of iron roofing. In first cost the two materials are about equal, but as the Uralite sheets are of much less weight than the iron, the cost of construction is less.

The composition of Uralite, which is unacted on by heat, cold, or water, is entirely mineral It consists mainly of short fibres of asbestos; these are reduced by the aid of most elaborate machinery to a fine wool-like texture, and mingled with gela-

tinous silica and a small amount of chalk. The reaction of these substances on each other, when submitted to heat and pressure, gives a material in which the silica, restored to its normal state, cements the asbestos into a firm substance, with a hard tough surface, not offering any tendency to laminate, and which, when formed into sheets, may be used for building purposes, and can be regarded as practically indestructible.

CHAPTER III.

FIRST PRINCIPLES IN LAYING OUT A WORKS.

AMONGST the first principles to be considered in laying out a works are the ways and means of transport, both as regards the raw materials and the finished products. In the nature of things the raw materials far exceed the manufactured goods, in bulk and weight. Where the works have good water connections the greater part of the raw materials may be brought in in this way, as water carriage is generally far cheaper than railway transport, but, as pointed out in our first chapter, provision must also be made for a railway siding into the works, as well as a good roadway for ordinary cart traffic. The width of the roads should be sufficient to allow one cart to pass another, and the road should have a slight fall from the centre to each side for draining the surface.

In close proximity to the line of railway and the wharf should be placed such buildings as the power house, and those process buildings where large quantities of fuel, or raw materials, will be used; and ample space should be allowed for storage of the supplies for these portions of the plant. Provision must also be made for the disposal of the large amount of ashes and clinker from boilers and furnaces when dealing with this question of coal storage. In cases where the cinders from the furnaces are not required for road making within the works, there is generally no difficulty in getting rid of them where there is a railway siding into the factory. Most railway companies will take them away, free of charge, for use in ballasting the line.

The several buildings required for the process or manufacturing operations should next be considered, as to their size and relation to each other. The chief point to be kept in mind in this arrangement of process buildings is to plan them, as far as possible, in such a manner that the development, from the

state of raw material to that point where the finished product is delivered to the stores or loading deck, proceeds in natural sequence

Bearing this point in mind, the process buildings can be kept together in a separate block from such buildings as are relegated to stores and to workshops in connection with the upkeep of the factory. In most large works the artificers employed in the upkeep of the establishment, though forming a large item in the total expenditure, are a necessity, and nearly every type of artificer is required. Thus we have the mechanic's shop, the electrician's shop, the blacksmith's shop, and the plumber's shop, all of which can be grouped together; and forming another group of buildings in close proximity to the one last mentioned we have the carpenter and joiner's shop, the painter's and glazier's, and the bricklayer's stores. With regard to the first group, comprising the mechanic's, electrician's, blacksmith's and plumber's shops, a very good arrangement is to place the mechanic's and electrician's shop in the centre, with the smithy on one side and the plumber's shop on the other, allowing room for extending laterally each one of this row of shops.

In the arrangement just suggested, the reason for placing the smithy and the plumber's shop on the outside is that in each of these cases a large supply of stores is necessary to replace those consumed. The plumber, in addition to considerable quantities of made-up articles, also requires a large platform on which he can roll out his sheet lead for cutting into the various shapes required for the miscellaneous vessels and articles which come within his department of construction.

In addition to these buildings, the store for general supplies must not be lost sight of. The term "general stores" includes such goods as shovels, picks, rakes, hammers, buckets, brooms, brushes, valves, taps, asbestos, glass and earthenware goods, and clothing or rubber goods used in special processes or under special circumstances. On account of fire risks it is best to make the oil store a separate building, isolated from the other structures.

The foregoing remarks as to the arrangement of buildings, etc., apply, as will be assumed by the reader, to a works of some magnitude. In such a works, the general stores is best placed near the office block, as the goods need frequent replenishing,

and are so numerous in detail as to require a special storekeeper in charge, who will be in touch with the office staff.

It is customary for the mechanic's shop to keep a small stock of various fittings, nuts, bolts, files, pipe fittings, such as tees, elbows, valves and cocks of small sizes, of which the foreman keeps account, so that the different departments are charged with renewals and repairs. The general storekeeper issues these supplementary stores from time to time.

The same remark applies, to a certain extent, to the carpenter, as regards screws, nails, sandpaper, glue, etc.; to the plumber, for some of the smaller supplies he requires from time to time; and so each tradesman, in his turn, draws from the general store to replenish the stock which he keeps in his own workshops, as it is obvious that he could not be running to the general store whenever he wanted some little article

The more bulky materials used by the different tradesmen are unloaded at their shops or stores, and they should account to the general storekeeper for them.

The bricklayer's store is mainly an enclosed yard, with the exception of a shed for storing such material as cement, ropes, ladders, blocks, tackle, and tools, as most of the materials required by the builder are not affected by the weather.

A plentiful supply of weighing machines are very necessary adjuncts to a works dealing with large supplies of materials, and will quickly repay their cost. One of these, say a 10-ton weighbridge, should be placed on the jetty (assuming the goods are coming in by water), and another at the entrance to the railway siding, while various smaller ones will be required about the works.

It may be that the weighbridge for goods coming in by rail can be so situated as to serve for weighing also carts coming in by road, but in such a case the weighbridge should have sunk rails, so as not to offer any obstruction to a cart being taken on to it. The weighbridge on the jetty might in many cases be sufficient if of 5-ton capacity, or even less, as there is not the weight of the trucks to take into consideration as on the railway weighbridge, the skips for raising the goods probably not weighing more than 10 cwt.

One or more travelling cranes should be provided on the wharf, and these should be on rails the same gauge as the rail-

way—4 feet $8\frac{1}{2}$ inches—so that, if required, they could be used for breakdown emergencies anywhere else on the works, the railway being connected up to the wharf. If the site will permit of it, the wharf should be large enough to accommodate two vessels coming alongside, if depending on the tide, as much time may be lost where a vessel has to wait for its berth and so miss a tide, as well as the important question of demurrage arising.

A light tramway system throughout the works is in most cases a very great saving in the transportation of goods from one department to another. A 2-ft. gauge light rail, with turntables at convenient points, is both cheaply and easily installed. In some cases an overhead runway system could be used to great advantage.

In most modern factories electricity is now superseding other forms of power and lighting, and as electricity lends itself so readily to distribution, the disposition of the power house will be best consulted as regards its proximity to the point where the fuel can most conveniently be unloaded. If the fuel should come in by water, then, if the power house is placed close to the wharf, this will allow of a gangway branching away from the main wharf, and dividing into several bays, on which lines of wagons, of the contractor tip pattern, can be run and tipped into the bays opposite the boilers. A modern power house will be found fully described in Chapter IV., in the design of which the principles here advocated are embodied. The clinker and ash from both furnaces and boilers are more often than not required for road-making in the works themselves, so that we need not take into consideration the handling of these residuals in dealing with the laying out of a new works

As regards the electricity mains for the distribution of current, our preference in the case of most chemical works lies in the direction of carrying these overhead.

Workshops.

In works where the finished products are sent away in drums, casks, or boxes, provision will have to be made for the storage of these. Where casks are required a cooperage would be necessary, and if boxes are also required a box-making department and cooperage could advantageously be organized in conjunction

with the carpenter and joiner's shop, and the same saw-mill could be utilized for both purposes. A saw-mill suitable for an averaged-sized works and capable of turning out the packing cases and boxes, and also dealing with the usual routine work of repairs and upkeep to other parts of the factory, is described in the Appendix.

Boxes are used in the following trades, amongst others: Soap-making, the manufacture of starch, laundry blue, candles, explosives, cyanide, disinfectants, dyes, inks, borax, essential oils and essences, drugs, camphor, soda, Glauber and Epsom salts. In many of these industries the boxes for shipment have to be lead-lined, and therefore, after leaving the carpenter's hands, are passed on to the plumber, and from him to the packing department.

In dealing with the subject of workshops we would draw attention to the necessity of disposing these in such a manner as to ensure safety from fire. With this object the joiner's shops and saw-mill should, so far as possible, be kept away from the furnaces or power-house. It is within our knowledge that a large joiner's shop in a works of quite recent construction is only separated by the width of a roadway from the boilers and chimney stack of a very large power plant, the sparks from the chimney of which have been seen by us to fall on the roof of the joiner's shop.

The same consideration should place stores containing inflammable material safely away from furnaces or from positions where sparks from a chimney could reach them.

If locomotives are used about the works, a spark arrester is generally fitted to the chimneys of these. In April, 1909, a fire occurred at Port Sunlight, resulting, as supposed, from a spark from a locomotive engine falling upon some resin barrels stored in stacks in one of the "resin fields". The damage was estimated at about £6000. In our own experience a quantity of nitre bags that had been put out to dry, although a long way from the railway, were set on fire by a falling spark from an engine.

The Drainage System.

In our first chapter, in dealing with the selection of a site for a new works, we have already spoken of the extreme im-

portance of a good drainage system in the laying out of a factory. We may now indicate at greater length some of the points to be kept in view when dealing with this important question.

The best position for the main drain is in the centre of the main road or roads, according to the extent of the works. The intercepting drains leading to the main should be laid with a good inclination, and never at right angles to the main drain. No inclination less than 1 inch in 10 feet should be given to any of the drains. Where the depth of the main drain permits of considerable fall, the drains, or the general trend of them, should be given the full benefit of the fall by a gradual inclination to the main. A vertical drop is bad in many ways, as the sudden flush caused by an unusually heavy downpour of rain will often carry a heavy deposit, which, precipitated through a vertical shaft, will tend to block up the outlet. Serious stoppages in a branch system can frequently be traced to this bad arrangement of connecting the smaller drains to the mains. All bends in the drains should be easy.

Joints of cement or clay made in the laying of drain-pipes are apt to squeeze through at the joints, and care should be taken, as each joint is made, to leave the pipes quite clear of any obstruction of this nature. Too much attention cannot be given to the laying of drain pipes The careless manner in which drains are so often laid called forth the remark of a well-known architect that the laying of drain pipes in many cases would be more properly described as burying them. The pipes should be selected for their perfect glazing, soundness and hardness of material, and the spigot and faucet ends should be well shaped.

Manholes should be placed at suitable places, and inspection boxes should be provided at every junction.

Foundations.

With regard to the foundations of buildings, much will depend on the nature of the structure and the weight to be carried. In the case of many of the lighter buildings, if the ground is of good, sound substance, it would be sufficient to cut the trenches and ram well with heavy rammers previous to putting in the brick footings, but in all cases where any con-

siderable weight is to be carried, or where any tall structure is to be erected, a good concrete foundation should be provided, after well ramming the excavated site.

In the case of inequality in levels of ground, where footings have to be cut in shelves it is well to bring the concrete foundations up to one common level before commencing the brickwork footings, in this way minimising the unequal settlement which is often caused by the shrinkage of the mortar joints when carried up at different levels.

Water should not be allowed to remain in foundation trenches; it is very essential that they should be kept dry, as good work largely depends on this. If by any chance mud has collected in the bottom of a trench, it should be removed before putting in the foundations. A good deal of trouble through unequal settlement can be traced to the brickwork footings being allowed to get saturated with water in the trenches.

Where concrete foundations are put in, they should be not less than 6 inches wider on each side than the bottom course of footings. Concrete laid on a previous day should be well wetted before another layer is added to it.

Retaining Walls.

In order to prevent the lateral shifting of the ground in such cases where there is a great difference between the levels, it will be found necessary to build retaining walls Before actually commencing any buildings, trial pits should be dug at different points of the ground to test its nature, as this may affect the disposition of the buildings As the result of these trials it may be found advisable to place such a building as a chimney-stack, for instance, in a different situation from that originally contemplated, as a better foundation may thus be secured than would be the case if this precautionary measure were not taken, and we would strongly advise a fresh disposition of buildings or plant in preference to using piles for securing an adequate foundation.

Fire Station and Appliances.

Any large works is now considered quite incomplete without its fire station and appliances, and in laying out the water mains hydrants should be placed at different points, with reels of hose

in suitable boxes, which should be readily accessible at the shortest notice, and so arranged that they can immediately be brought into play.

All large works should be equipped with a portable steam fire-engine, and the works staff should be organized as a fire brigade, with officers whose duty it should be to drill the men regularly and efficiently, prizes being offered for efficiency and smartness in turning out

A very suitable engine for use in large chemical works is Merryweather's improved double-cylinder "Greenwich" steam

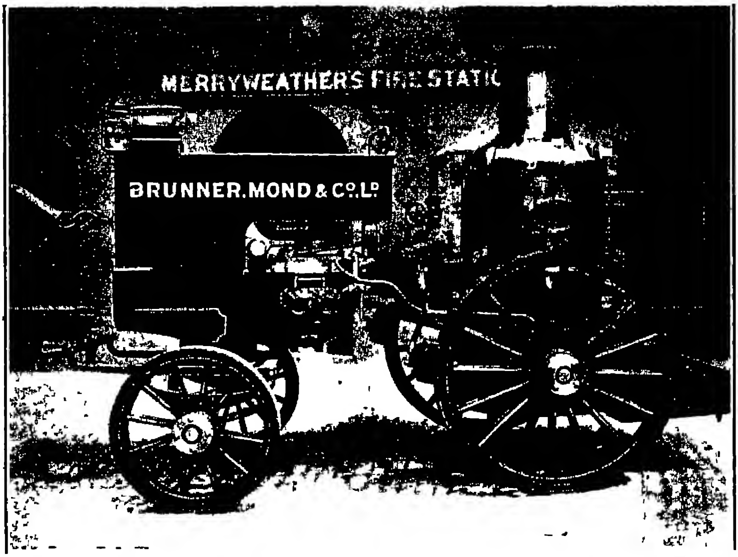


FIG. 1—"Greenwich" Steam Fire Engine.

fire-engine, which, as shown in Fig. 1, is used by Messrs. Brunner, Mond & Co., and some details of its construction are here given.

The increasing demand for powerful steam fire-engines of light weight has caused Messrs. Merryweather to develop their well-known double-cylinder engine, and to adapt it to run at high speeds. Although a slow-speed engine with a long stroke has many advantages, it is manifestly incapable of competing with a high-speed engine in the matter of lightness. Keeping this in view, the makers have constructed the "Greenwich"

engine, which, while retaining most of the best features of their old double engines, combines such novelties and improvements as to render it possible to obtain the same amount of work with a reduction of more than 20 per cent in weight, and without in any way sacrificing strength or durability. The "Greenwich" engine is built on the same principle as the "Metropolitan" (London Brigade) engine, but has double cylinders and pumps, and delivers more than twice the quantity of water per minute, whilst weighing only a few hundredweights more, as various mechanical improvements have been introduced into its construction.

In the new pattern engine, the makers have aimed at securing maximum power with minimum weight, consistent with strength and durability. They have also brought to bear their long experience in fire-engine manufacture in perfecting the other parts that enter into the construction of a steam fire-engine, including quick steam-raising of boiler, general convenience of engine for working, accessibility for repairs, durability, strength and security, and elegance of appearance and finish.

The superiority of the "Greenwich" engine for heavy work is not maintained merely because of its quick-steaming properties and remarkable pumping capabilities, but also on account of the exceedingly high water pressure maintained continuously whilst the engine is worked. This is an all important test of efficiency.

The engine is constructed entirely independent of the framework, and is complete in itself. The frame also carries (*a*) Driving seat, and seats for firemen if required; (*b*) a commodious iron hose bunker, attached to the front of the frame, or large hose and implement box; (*c*) brackets for suction pipe; (*d*) bunkers for coal; (*e*) wrought-iron fore-carriage of neat and strong design, (*f*) strong wrought-iron axles, with high wood-spoke wheels for rapid travelling.

The boiler is of the type known as Merryweather's patent quick steam-raising boiler. Its various special features may be summarized as follows. It is stoked from behind, and can therefore be fired whilst the engine is *en route* to a fire; steam can be raised from cold water in three minutes from lighting the fire, and to 100 lb. pressure in from six to eight minutes, according to the

quantity of water in boiler, and other circumstances; it maintains steam to full working power continuously, being of ample capacity, even when a common class of coal is used; for examination or repairs the fire-box and tubes complete may be dropped away from the shell by removing the bolts round the angle-iron joint rings. The tubes are always full of water, and the crown-plate is covered at whatever inclination the engine may be worked. The boiler is separate from the engine, and is not

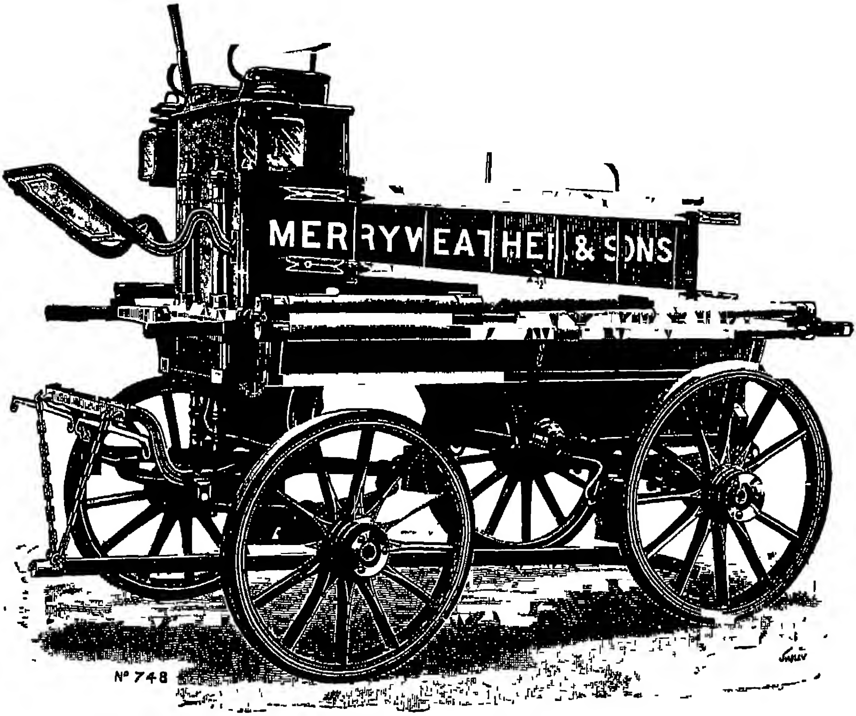


FIG. 2.—The "Greenwich Manual".

subject to the working strain. The special design of the boiler renders it less liable to prime than some other makes The boiler is made specially strong; it is lagged with highly polished sheet brass, and is provided with all the necessary fittings, safety valves, blow-off cocks gauge glasses, patent injector and feed tank, together with coal bunkers behind, with a foot-plate between for men.

A useful manual engine, the "Greenwich Manual," is shown in Fig. 2.

Very frequently it would be found advantageous, if not, indeed, rendered absolutely necessary by the exigencies of space, to utilize the boiler pump in combination with other apparatus for fire extinguishing. In any case the utility of such an arrangement is at once apparent Such a plant (shown in

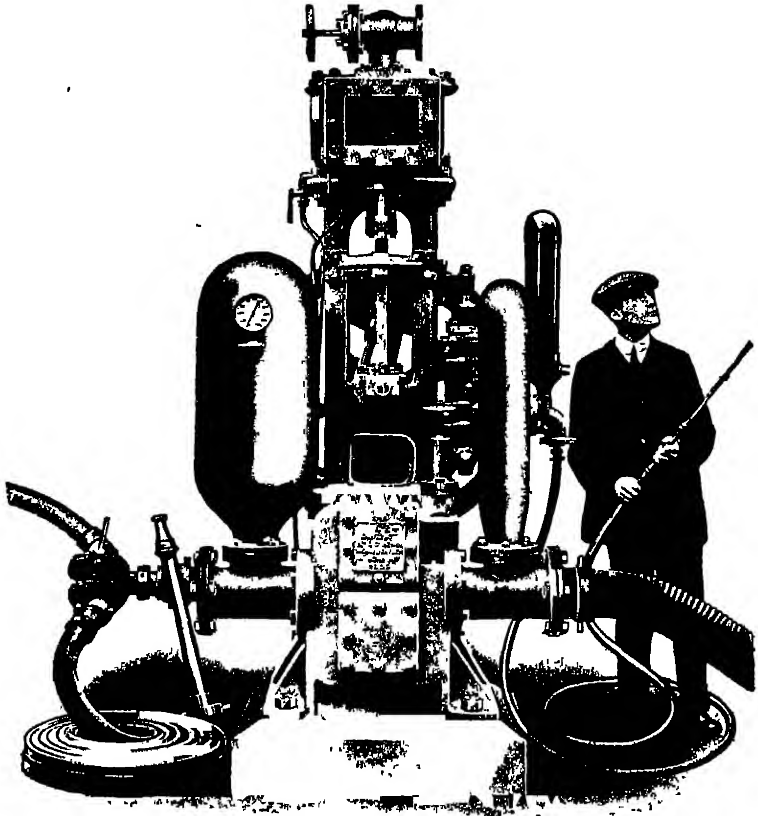


FIG. 3.—Midland Railway Patent Fire and Boiler Feed Pump.

Fig. 3) has been designed by Messrs. Merryweather, and combines a feed-pump for the boiler, and, when occasion demands it, a reliable fire-extinguishing apparatus. The fire-pump may be connected with indoor and outdoor hydrants, and will deal effectively with any supply up to 500 or 600 gallons per minute. This engine is composed of a 16-inch steam cylinder, which is

inverted over the fire pump, and is 10 inches in diameter, with a stroke of 8 inches, and the steam is conveyed to the pump cylinder by a cast-iron distance piece, upon which two steel crossheads work on guides. One of the crossheads is connected to the manganese-bronze pump-rod, and the other by a steel rod to the steam piston There are also a connecting-rod with gun-metal end, and fly-wheel and crank shaft. The pump is double-acting, made of cast-iron, with gun-metal plunger plates, valve-seats and liner. The valves are specially designed for fire-engines, of india-rubber with backs of gun-metal, arranged under two covers, so that ready and direct access to them is assured. There is also fitted to the pump an automatic relief valve, whereby, with the pump working, the sudden effects of the closing of hydrants or outlets may be met When used as a feed pump the disengaging gear stops the fire-engine. The capacity of the feed pump, which is of 4-inch diameter with 8-inch stroke, is ample for the requirements of a 200 horse-power boiler working at a pressure of 180 lb, and is made of cast-iron, with hot-water valves, bronze piston-rod and gun-metal liner. The pump is fixed on an angle bracket, which is cast on the distance piece of the engine, and driven direct from the upper crosshead. The whole pump may be removed quite separately when required.

If the feed-pump only is being used the steam is supplied to the engine by means of an automatic pressure-reducing valve, an obvious economy. For a minor outbreak of fire a small supply may be obtained direct from the feed-pump without necessitating the coupling of the main pump. All the various parts of the pump may be interchanged with any other similar, and all necessary fittings will be found included.

Fig 4 shows a complete system of fire protection as adopted by a large establishment in Scotland, and carried out by Messrs. Merryweather

The supply of water consists of a mill-dam at a considerable elevation above the yard, communicating by means of a 27-inch pipe with an open mill-race at the opposite end of the premises. As the 27-inch pipe could always be depended upon for supply, it was decided to connect the suction pipe of a stationary fire pump to this, and to lead cast-iron mains from the pump to the various parts of the premises. The pump selected was one of

Merryweather's direct-acting long-stroke pumps, with a steam cylinder 12-inch diameter, and pump $7\frac{1}{2}$-inch diameter, with a stroke of 2 feet. The pump barrel, valves, and seatings are of gun-metal. The pump is fitted with capacious copper air

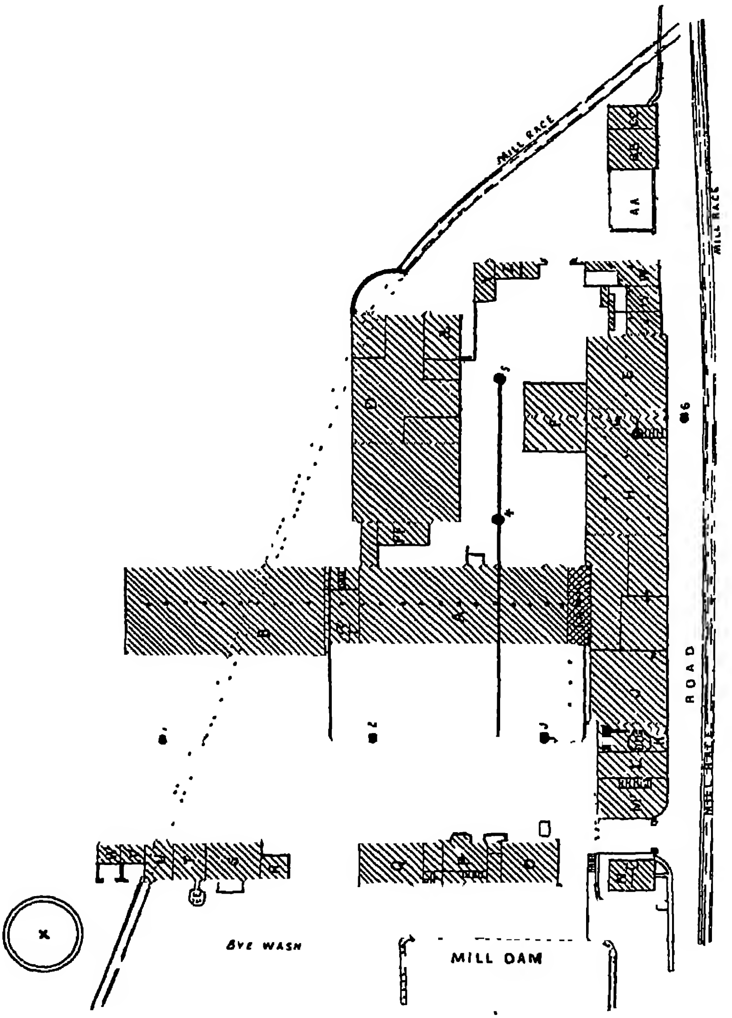


FIG. 4.—Complete System of Fire Prevention for Industrial Establishments, by Merryweather & Sons, Ltd.

vessels, pressure gauge, sluice valves, etc., and is fixed in an engine-house contiguous to the boilers supplying the powerful engine of the mill. Steam is used at a pressure of 60 lb. per square inch, when the maximum work is obtained from the fire-

engine, but it may be started with steam pressure as low as 20 lb., which pressure is always available in one of the boilers. The pump is also connected to a large tank placed on the top of the building, so that in the remote contingency of there being insufficient steam in any of the boilers to start the pumping engine, the mains could be charged and an efficient jet thrown from any but the highest hydrants during the time the steam was being raised.

Leaving the pump, the delivery main is carried in a straight line to the extreme end of the yard, and is fitted with three ground hydrants to protect the offices, gasworks, etc. A branch is carried into the mill and up a staircase between two blocks of buildings, each about 120 feet long, one having two stories and the other three stories and attics. As the processes in this department are carried on with a considerable amount of moisture, both in the atmosphere and the material, there is no great danger of a rapid spread of fire. The hydrants on each floor of the staircase were, therefore, considered sufficient to protect both buildings. Another branch is carried under the mill to the back-yard, around which the most hazardous buildings are placed. Hydrants are placed on each floor on the staircase, as it was considered that no one would attempt to use the hose in case of need unless a safe and ready retreat was provided. The store adjoining contains the valuable stock of raw material, and this is protected on two sides by a hydrant in the mill avenue, and another in the yard. Facing the mill is the mechanic's shop and a room which is most liable to accident of any of the buildings, as stones or other foreign matter occasionally pass into the machines. This building is protected by a hydrant in the yard, and as a further precaution small hoses are always connected behind each machine for immediate use in case of accident. A hose cupboard is placed against the wall near each underground hydrant, containing stand-pipe, hose, branch-pipe, hydrant key and hose wrenches, and above each inside fire valve the hose and appliances are hung upon boards, so that they are always in sight and easily accessible. At a trial of the apparatus a jet was thrown considerably above the highest part of the mill, and four jets were thrown simultaneously.

Fig. 4 shows a plan of the buildings, the suction-pipe for the steam fire-engine being carried from the mill-race to engine,

and the black lines shown being the fire main pipe. The numbered dots on main are underground hydrants.

Fig. 5 shows a very useful hose cupboard intended for fixing against a wall near an underground hydrant. It is made

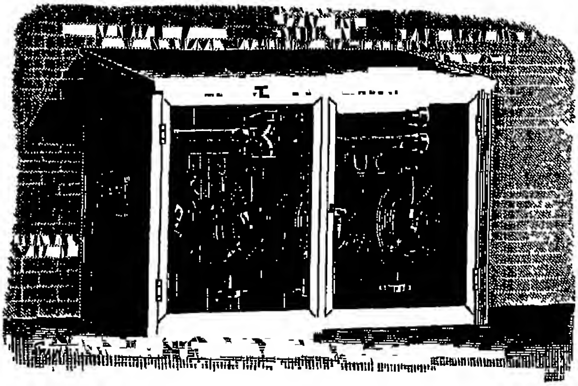


FIG 5.—Hose Cupboard.

specially strong for outdoor use. It will contain four lengths of hose, standpipe, two branch-pipes, nozzles, hose and nozzle wrenches, etc. Two glass doors are fitted with good lever lock and two keys. At the side is fitted a small box with glass, to contain one key, so that, should a fire occur, any one can break the glass, get the key, and open the cupboard to obtain the necessary hose, etc. The other key is kept by some responsible person connected with the establishment. Similar cupboards are also used inside the buildings, being placed in halls, corridors, and on staircases near hydrants, and are made in each case to suit premises, and of material and size required. Fig 6 shows a similar cupboard to Fig. 5, but designed to contain pillar hydrant, as well as hose and fittings. This can also be

FIG. 6.—Hose Cupboard with Pillar Hydrant.

fitted in or out of doors, and has key box with glass side as described above. It has a single glass door, lock, keys, and the necessary hooks, etc., to carry hose, branch-pipe, nozzle, wrenches, etc.

FIG 7.—Messrs. Crosfield & Sons' Fire Brigade with Engines, and Escapes Manned.

The two steam fire-engines, made by Messrs. Shand, Mason & Co., of London, are continually kept under steam, being connected with the works steam main. The large steamer is adapted either for works or outside fires; it is provided with a

6-inch instantaneous suction, has five instantaneous coupling deliveries, and is capable of pumping 750 gallons of water per minute. It is also fitted with quick-hitching harness, and carries first-aid requirements, including a folding stretcher.

The small steamer is fitted with a fixed 4-inch suction, and has a delivery of 350 gallons per minute. This engine may be run out by hand. Both engines use oil fuel.

Messrs. Joseph Crosfield & Sons, at Warrington, have organized an excellent works fire brigade, consisting of thirty-six officers and men. The training of the brigade is of the most comprehensive character, and is continually revised to be in accordance with the most modern practice Drills are held weekly, and comprise wet drills, hose running, ladder and escape practice, Pompier scaling drill, and knotting and life-saving work. In addition to the general equipment of the fire station, which consists of two steamers, two escapes, smoke helmet equipment, hose carts, electric fire alarms, automatic fire indicators, etc., each department in the works has its own apparatus, each piece of apparatus having a man in charge, who keeps it in order and uses it in case of fire. The brigade attends outside fires when requested, charging the ordinary fire-brigade rates.

Many visitors to Messrs. Crosfield's works have seen this efficient brigade turned out. The engines, with escapes manned, is shown in Fig. 7.

Ambulance Arrangements, etc.

Accidents of varying degrees of seriousness are inevitable in any large works, and it is becoming more general to make provision for dealing efficiently with these unfortunate occurrences The most enterprising firms in the chemical and allied industries have during recent years shown an increasing solicitude for the welfare of their workpeople in this respect, and this policy has been found advantageous both to the employer and employees. Prompt and adequate attention to injuries frequently results in reducing the severity of the mishap. The rendering of first aid on the spot will in many cases do much to reduce the liability for compensation, but in any large works where the employees are numerous, it is necessary, in order to

secure the advantages resulting from prompt treatment, to organize an efficient system of dealing with accidents.

In the most up-to-date factories, great care is now taken in dealing with this important question. The necessity for the reporting of accidents of any degree of seriousness is alone ample reason for the extreme care which is now being shown in such large works as those of Messrs. Brunner, Mond & Co., Ltd., or Messrs. Lever Brothers, Ltd, for instance. Both these firms have established works' surgeries; at Port Sunlight there are no fewer than six of these, fitted with all necessary appliances, where efficient first aid is given. Messrs. Brunner, Mond & Co., Ltd., require their men to go to the works' surgery to have even the slightest abrasion of the skin properly cleansed and protected. This is one of the rules of service with the company, and the result is that many cases of blood poisoning have thus been prevented It would undoubtedly be well if many employers, who at present have no such careful system of dealing with slight injuries, would follow the example of the great Northwich firm. The value of such a procedure is amply proved by the fact that the total cost for compensation in Messrs. Brunner, Mond & Co.'s works is under 3s. 2d. per £100 of the wages paid

At Port Sunlight, in addition to the six works' surgeries, there are eight ambulance stations in convenient positions in the various departments, each of which is well equipped for dealing with accidents. First-aid boxes are ready in all the surgeries and ambulance stations, and here also are posted lists of workpeople qualified to use the first-aid boxes. Cuts and scratches are dealt with by the ambulance staff in the surgeries. There are always at hand in every department workpeople able to render first aid, while a resident doctor is available for the treatment of serious cases. Some system based on the experience of such works as those mentioned might easily be adopted in all large establishments.

At Port Sunlight an Accident Committee is formed from representatives of the workpeople, careful rules have been drawn up, and these provide for investigation of accidents. According to Rule II. the principal duties of each committee shall be: (*a*) To promptly and fully inquire into and report to the company upon any personal accident, happening in the division (of the

works) represented by the committee, which prevents the injured person from following his or her usual occupation for at least six working days after the accident, and the cause of the same, and to make recommendations so as, if possible, to prevent the repetition of such accidents The committee shall have power to visit the site, make full inspection, hear witnesses, and generally investigate all the circumstances connected with the accident. (*b*) When specially requested by the company to do so, to recommend the compensation (if any) to be offered to any injured person or persons. It is not sought to bind such person or persons to accept such compensation. (*c*) To nominate quarterly two members of the committee, who, along with the divisional manager and a foreman nominated by the company, shall make periodical inspections of the division, point out defects (if any), and make recommendations calculated to prevent accidents of any kind.

Messrs. Crosfield & Sons have an Ambulance Brigade, thirty-three strong, of whom three served through the South African War; all are in possession of the medallion; twenty-nine are in possession of the St. John's Ambulance Association Label, and twenty hold efficiency badges; twelve are members of the Royal Naval Auxiliary Sick Berth Reserve, which serves to recruit the Naval Sick Berth; eleven belong to the Military Home Hospitals Reserve, which serves as a reserve to the Army Medical Staff. Men on passing their third year are given uniform. There are eight stations in the works where first aid can be given, and in each centre are posted the names of the men of the brigade in their section. To still further assist recognition badges are worn by these men.

The central ambulance station, situated near the main chemical laboratories, is in charge of a qualified man. The equipment consists of stretchers, splints, chairs, tables, hot and cold water, bandages, lint, carbolized water, alcoholic ferric chloride, carron oil, olive oil, picric acid, solution of bicarbonate of soda, etc. The sub-stations are furnished with lint, bandages, carbolized water, carron oil, olive oil, picric acid, plaster, wash bowl, sponge, and scissors.

At the main station a record is kept of all cases treated throughout the works, and each month these are classified under the heads of nature, cause, and where occurring. These

analyses are sent to the departmental managers to enable them to prevent a recurrence, or at least to minimize the chances of a recurrence. All lads and men are encouraged, by free lectures from qualified medical men, to learn ambulance work, and one hour per week is allowed out of the firm's time for ambulance practice. To further stimulate interest a Crosfield Division of the Warrington Corps of the St. John Ambulance Brigade was formed in 1905, the members being required to put in a certain number of drills to keep them efficient in ambulance work. The following is taken from the annual report, after inspection, for the past four years. "1907 Considering the short notice of the inspection I consider the parade and work perfectly satisfactory. 1908: A very smart Division 1909 · This Division appears to be in a high state of efficiency. 1910: The drill, both foot and stretchers, was very smartly performed, and the application of splints and bandages showed the men had a thorough knowledge of the work. I consider the Division is efficient"

The men are also encouraged to form teams to compete for ambulance prizes at Open Ambulance Tournaments. The Ambulance Division attends duty at the Athletic Sports or other public functions when required During the winter instruction is given in first-aid to new classes by the honorary surgeon. Lectures on ambulance work and sick nursing, with practical work, have been given to the girls also, and have been well attended.

Eleven years ago the firm gave a challenge shield to be competed for by all corps in the No. 4 District of the St. John Ambulance Brigade. Colonel Trimble, V.D, M.D., C.M.G., the deputy-commissioner, states that this shield has stimulated, in no small degree, the interest in ambulance work in the North of England.

CHAPTER IV.

THE POWER HOUSE

TAKING a medium-sized works, where a battery of half a dozen boilers of Lancashire type, measuring 30 feet long by 8 feet diameter, is installed, and assuming that the factory is of such a nature as to require continuous working, an arrangement similar to that shown in the drawing (Plate I.) would be very suitable. Here it will be seen that the coal bunkers are arranged directly opposite the main battery of boilers, so that we have three separate longitudinal bins with gangways dividing them, on which a light tramway suitable for tipping wagons may run. The coal can be tipped from these wagons from either side of the gangways into the bins, which are readily accessible to the stokers engaged on the boilers It will be noted that we are not describing a plant in which the latest type of elevators and conveyors are used, as it is only where the largest and most extensive works are concerned that plant of this type, with overhead bunkers and automatic feeds, can be economically employed, the heavy initial capital expenditure placing such elaborate plant out of the reach of the average manufacturer.

Whatever the size of the plant may be, it is desirable that the coal-store should be covered over. Ample space should be given from the face of the boilers to the commencement of the coal bunkers, so as to enable free use for the tools used for stoking and clinkering, as well as leaving a clear way in front of the boilers for conveying the ashes to one end of the boiler-house, where an elevator could be placed for disposing of these The space between the face of the boilers and the bunkers should not be less than 12 feet, and we prefer even more, say, 15 feet, this giving ample room for a covered trench in front of the boilers for blow-off pipe connections.

Possible future extensions as regards the boiler-house, in common with other buildings, must be kept in view, and a suggestion for future extensions is shown here in dotted lines. It will of course be obvious that there are many ways of effecting the same object. The one shown would make a good arrangement

Where more than two boilers are employed, of the size mentioned, it is always economical to put in an economizer, with provision for adding a further one as circumstances demand, when increasing the number of boilers.

With this object in view the flue at the back of the boilers can be so arranged as to run parallel with the flue over which the economizers are placed, with dampers in suitable positions, so that the flue gases from the boilers can be worked through the one flue direct to the chimney, or, by operating the dampers, can pass through the economizer flue before their final exit to the chimney.

Revolving vertical dampers on the main flue are always to be preferred to the sliding type, as being less likely to get out of order.

The nature of the works will decide whether an independent chimney-stack is built for the power house, or whether one main works stack is made to serve for power house and for all other flues or furnaces in the works. Where the works are sufficiently large to warrant the expenditure, it is preferable to provide independent stacks, but here, again, possible extension of plant must be kept in mind in proportioning the size of the stack. In any case, the chimney-stack should be a separate structure, and not be built on to any other building Disastrous consequences have resulted from this latter practice in several cases, caused by unequal settlement between a much lighter building being attached to a heavy chimney-stack

A lightning conductor should be attached to the stack, with one or more points

Where the arrangement of the chimney is such as to have two flues entering at opposite sides, the one flue, say, taking the gases from one battery of boilers and the other serving another battery of boilers or furnaces, as the case may be, it is customary to build a mid-feather wall for some 20 feet or 30 feet high inside the chimney, in order to prevent the gases from the two sources

from baffling one another, which would happen if this mid-feather were to be left out.

The foundations for the chimney-stack require to be very carefully put in, owing to the great weight to be carried, and in carrying up the several courses of brickwork strict supervision should be maintained, to ensure that in no case should any catching up of the level be attempted by introducing bricks on edge or a thicker quality of brick or joints. The thickness of the bricks and joints should be kept uniform throughout. Except in chimneys of very large diameter it is necessary to have the bricks made in special moulds to suit the radius of the chimney in question, as to build a chimney with square bricks would involve very large joints, and the work should proceed with not less than one course of headers to every five courses of stretchers.

The chimney shown in the drawing is a very good example of a suitable works chimney, and it will be noticed how the brickwork gradually diminishes towards the top by offsets at distances of every 25 feet in height. Whether the chimney is finished off with an iron cap or stone or a vitrefied cap or stone depends to a great extent on the nature of the gases to be dealt with, and as to whether these would affect the capping

Reverting to the boiler-house, the best type of roof is boarded and slated, with a louvre running the whole length. A double-span roof is shown in the drawing, and any extension could be carried on in the same way The drawings show the setting of the boilers and general arrangement of the steam-pipes and run-off pipes connected with the blow-off from each boiler.

When a boiler has been blown out or let down for cleaning or repairs, provision must be made for refilling; for this purpose, directly over the man-hole of each boiler, and transverse to them, is arranged a line of water-pipe with a short connection, so that any boiler can be easily and quickly filled from this source. Of course the usual supply to the boiler when under steam is through the feed valves on the boiler front plate.

Where the quantity of water evaporated is taken account of, a water meter should be connected to the pumps feeding the boilers.

The feed pump or pumps for the boilers is preferably placed in an adjunct to the boiler-house, so that the working parts may

be kept free from the dust which inevitably rises during stoking and clinkering operations.

Touching upon the boiler setting, special blocks upon which the boilers rest are made by several well-known firms, between which it would be invidious to make a distinction, but in our own practice we have used the Poulton form of block, and have found it to be admirably suited for this purpose. These blocks are made in two sizes, to suit the width of side flue used. As in all fire-brick construction, care must be taken that all the fire-clay joints are as thin as possible and carefully made, and that the setting should not permit of any air being drawn into the flues from the outside, through the brickwork.

The main steam-pipe connecting the boilers should have expansion joints at suitable distances, and all pipes, and also the tops of the boilers, should have a good covering of non-conducting material. Here, again, the choice of such material is large, and the different kinds are almost too numerous to mention.

Apart from the benefit to be derived from the installation of economizers, a water-heater taking the waste steam from the engine or engines is recommended, and room for this can be found in the same house with the pumps, in some cases it is found convenient to place the heater over the top of the main flue at the back of the boilers.

Most of the makers of economizers prefer the feed-water not to enter them cold but pass through a feed-water heater first Where this is not done Green's system is to take a small pipe from the economizer to a pump which draws a small quantity of the heated water from the economizer and mixes it with the cold water, which is again fed into the economizer, thus making the economizer heat its own feed-water.

Although in modern works testing of the flue-gases is carried on at frequent intervals, still, the more common practice of watching the exits from the chimney, as the smoke inspector naturally does, for black smoke, makes it necessary that the stokers should always have the chimney-top in view, and this may be obtained by a skylight placed at such a position in the roof of each of the bays over the boilers as to effect this.

The engine-house may be built on to the boiler-house, or it may be a separate building, if thought advisable. Taking future extensions into consideration, a separate building would prob-

ably lend itself better for the carrying out of such extensions, and again, such outside conditions as possible condensing towers, or reservoir of feed-water for the boilers, might influence the design as to the separation of the power-house, or otherwise.

The engine-house we have in mind is more suitable for a works where electricity is employed mainly for driving the various machinery and plant, and provision should be made for an overhead traveller, running the whole length of the house, in order to quickly deal with any part of the plant in case of removal or repairs, and the door at the end should be sufficiently large, when fully opened, to admit of the passage of the largest piece of plant, be it engine or motor, that would be located in this house, and a smaller doorway framed within the larger one for ordinary use.

Whether the engine-house is separated from the boiler-house or not, ready access must be provided between the two, as the one is dependent so largely on the other.

A duplicate system of steam-pipes from boilers to engine-house is to be recommended as a safeguard against breakdown. It is preferable to place the floor of the engine-house above the ordinary ground level, so that the cables from the motors can be carried in suitable channels below the floor of the house to the switch-board.

Taking all things into consideration, we think it is desirable, as regards the engine-house, to contemplate a possible duplication of plant, and to make the building sufficiently large to accommodate this in the first case, as such a provision will probably meet all future requirements. It will be apparent, on careful consideration, that to provide room for a duplicate set of engines and motors would be nothing comparable with the extent of room and accommodation required for a duplicate set of boilers, and it is therefore worth while to build the engine-house sufficiently large to meet future requirements.

All valves, whether on pipes, boilers, or other plant, should be readily accessible, and permanent means for reaching them arranged in the case of those that are out of hand reach, to obviate the necessity of running for a ladder when sudden need arises for operating any of them.

Valves.—All valves belonging to main water supplies, gas supplies, and steam supplies, and also fuses of electric mains,

should be drawn out in a diagrammatic plan, with descriptions attached, and hung up in the time-keeper's office, so that in case of accident the valves shutting off different departments can be readily located and the particular section isolated.

Flues, etc.—Again, considerable importance should be attached to the disposition of flues, drains, and sewers underground, as these are often lost sight of. Plans of them should be kept, and any alterations should be recorded on these plans, in order to keep these up to date. Such procedure will frequently save much time and labour.

Automatic Stokers—In speaking of the boilers, although we have not described mechanical stoking, a combination is often found to be an advantage, by having the fire-bars actuated by a cam motion which helps considerably to keep the bars from clinkering.

Steam Raising.—It must be borne in mind that the modern practice in steam raising is to use much higher steam pressures than was formerly the case. Pressures of 200 lbs and upwards are now very common, and it is recognized that it is far more economical to raise steam at a high pressure than at a low pressure, and to use reducing valves to such plant as requires a lower pressure than that generated at the boilers.

A great many advocates in steam practice are to be found for superheating steam, and where this has to be carried to plant at long distances from the boilers, and where a great deal of condensation would naturally take place between the points of generation and application, the question of superheating deserves attention. Highly superheated steam is said to affect the surface of cast-iron, pitting taking place where the superheating has been carried to excess, but this has been chiefly noticeable in the faces of the valves of engines where superheated steam has been used.

Where high pressure is employed, the steam-pipes generally used now are steel-flanged pipes, and vulcanite packing rings form the best joints. Rubber is soon vulcanized and perishes where high temperature exists. Next to vulcanite, millboard or asbestos sheet, or thin gauze copper rings with a little red lead coated on them, form a good joint.

Where it is frequently necessary to break a joint, this is facilitated by giving the millboard or asbestos joint a coating of blacklead.

As a safeguard against gas explosions in the boiler flues, it is advisable that a 2-inch hole should be bored through the upper part of the dampers to allow unburned gases to pass through.

During recent years forced draught has come into use to a very great extent, especially where an inferior class of fuel is burned, or where the natural draught is not sufficient.

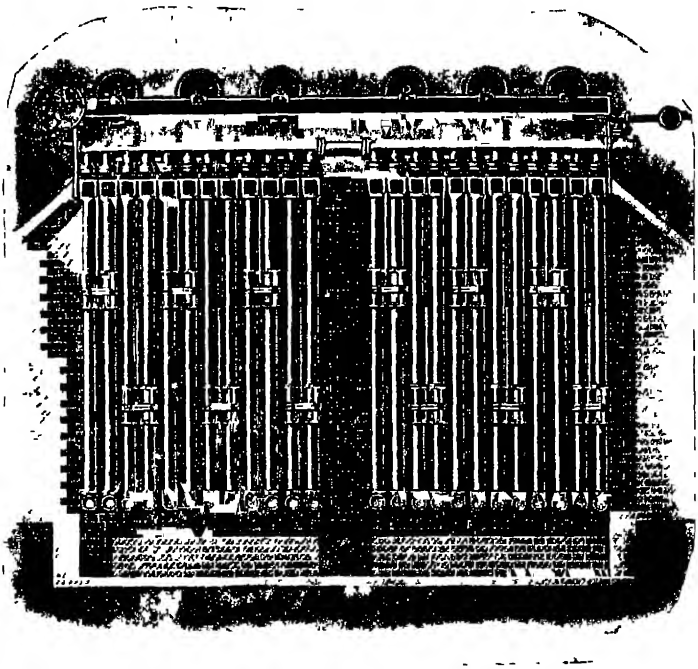


Fig. 8.—Green's Economizer Front Elevation

The Economizer.

It is well known to all steam-users that in the generation of steam the principal source of waste is the loss of heat by the chimney; this loss, even under the most favourable conditions, is much in excess of what is necessary to provide the requisite chimney-draught The utilization of this surplus heat, for heating up the boiler-feed water, is best effected by Green's economizer, and we are indebted to the makers, Messrs. E. Green & Son, Ltd., of Wakefield, for the illustrations, Figs. 8,

9 and 10 here given, which clearly show the construction of the apparatus.

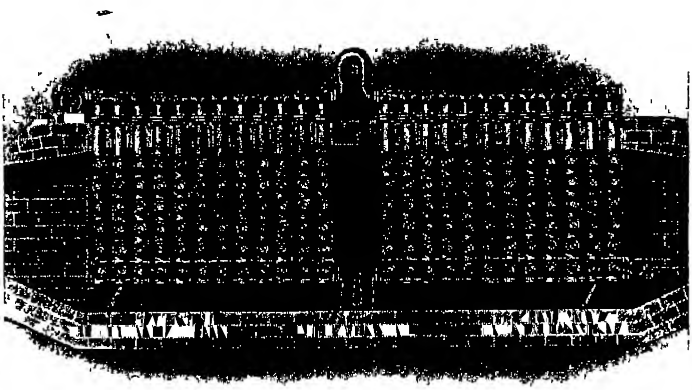


FIG. 9.—Green's Economizer Ground Plan Showing Soot Pit.

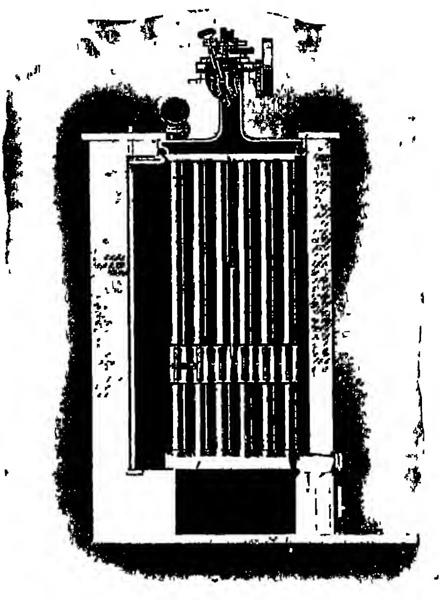


FIG 10. Green's Economizer · Cross-section through Economizer Chamber.

The hot gases pass through the economizer chamber to the chimney, and the difference in temperature between entering

and leaving is to a great extent absorbed by the apparatus and imparted to the feed water, which enters the boilers at a high temperature. The boiler power is thus augmented and a uniform and easy rate of steaming maintained, while a reserve

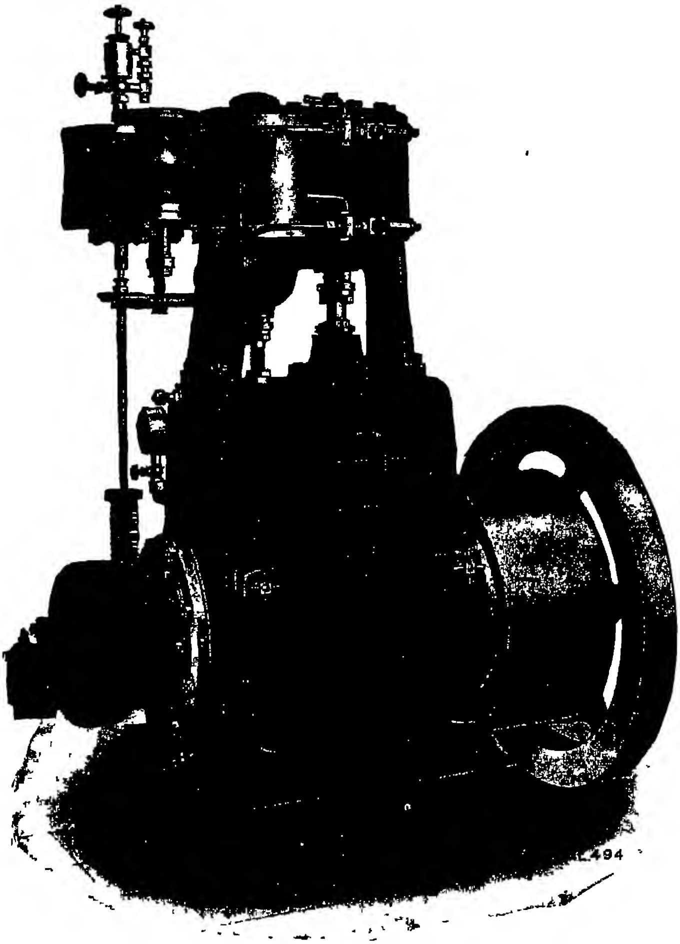


FIG. 11.—" Sentinel Junior " Simple Steam Engine, by Alley & MacLellan, Ltd.

of hot water at from 200 to 300 degrees Fahr. is always available. This latter point is of special value wherever a large quantity of hot water is necessary for process operations.

Heating the feed water by means of an economizer is not only a direct advantage on account of the saving in fuel, but it

prevents damage to the boiler by unequal expansion and contraction, which always occurs when the feed water is introduced cold. Green's economizer is too well known to require recommendation here; no modern boiler plant is considered complete without it. All parts are strictly interchangeable

The economizer consists of a series of cast-iron tubes, 9 feet in length by $4\frac{9}{10}$ inches in diameter. These are arranged in sections

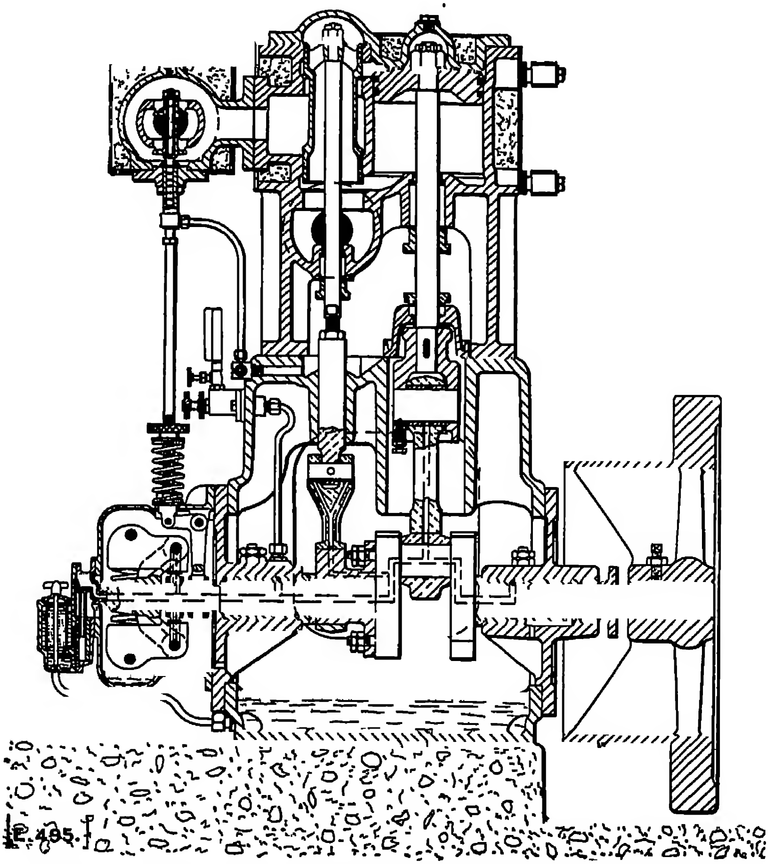


Fig. 12—"Sentinel Junior" Steam Engine, by Alley & MacLellan, Ltd. (Sectional Drawing).

of various widths, across the main flue, between boilers and chimney. When in position the sections are connected by branch pipes. The waste gases are led to the economizers by the ordinary flue from the boilers to chimney, and the feed

water is forced into the economizer by a boiler pump or injector. Each tube is encircled by a set of scrapers which keep the tubes free from soot, the scrapers being worked from convenient shafting or a small independent motor. Easy access is provided to all parts of the apparatus inside the flue.

In the installation of new steam-raising plant ample room should be provided for extension of the economizer apparatus,

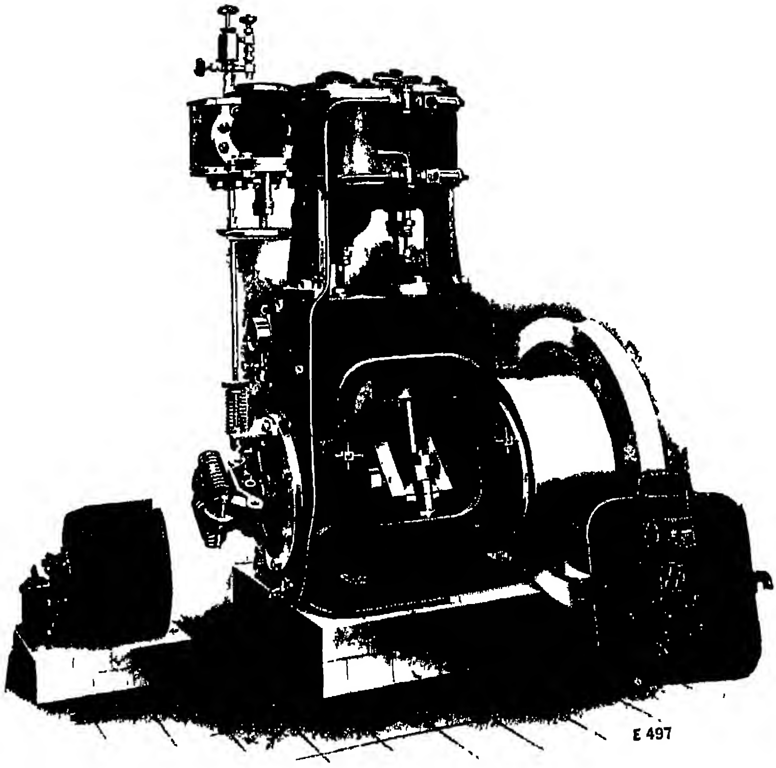


FIG. 13.—"Sentinel Junior" Steam Engine, Showing Accessibility of Parts

and if the apparatus is not put down with the boiler plant in the first instance, space should be provided for its subsequent installation.

STEAM ENGINES.

Of the importance of the steam engine in the scheme of power supply to any works, large or small, it is unnecessary to write at any length, the question of selection of plant is the

point to be considered here. Fig. 11 shows a type of engine, the "Sentinel Junior," made by Messrs. Alley & MacLellan, Limited, of Glasgow, which is suitable where small units are required, and which, while highly economical, is thoroughly well made, free from complication, very solid and strong, and

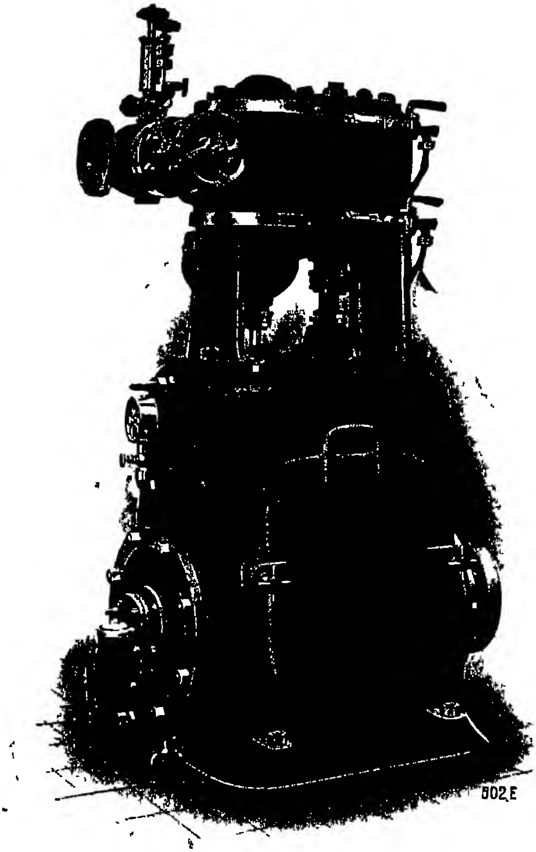


FIG. 14.—"Sentinel Junior" Fan Engine.

moderate in price. These engines are very useful for small lighting and power generators, fans for boiler draught and ventilation, centrifugal pumps, small factories and works, and for use with compressed air.

In the planning of these engines the makers have embodied a unique experience in engine manufacture, and their reputation

that no hesitation need be felt in adopting the "Sen-
ior". Close steam consumption is guaranteed on every
upkeep is extremely small, and the engines are fully
ic in oiling and greasing; all working parts are en-

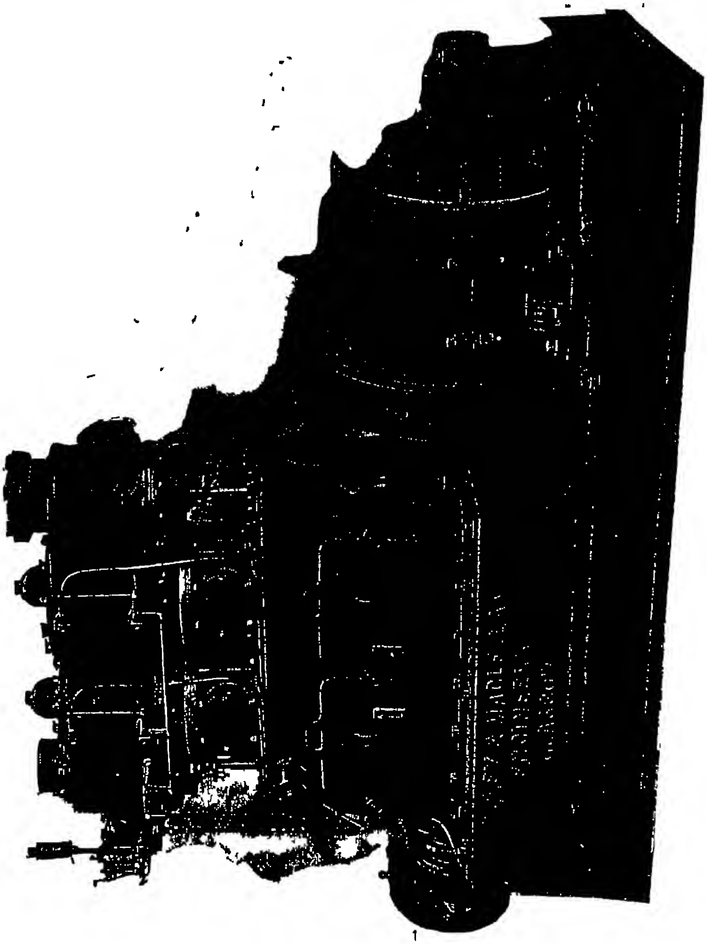


Fig. 15.—"Sentinel" Compound Double-Acting Steam Engine.

closed, and, for the purposes indicated, they may safely be regarded as eminently suitable.

It generally pays to use "Sentinel Junior" tandem compound engines for pressures above 100 lb. per square inch when exhausting to atmosphere and for pressures above 80 lb. when exhausting to a condenser.

Fig. 12 shows clearly the construction of the simple type

of this engine. In the tandem compounded form the high-pressure cylinder and its gear are placed above the steam cylinder shown in Fig. 11, which then becomes the low-pressure cylinder.

This type of enclosed engine is much superior to many of the wasteful open types, but although possessing all the advantages of the best make of enclosed engine, all the bearings

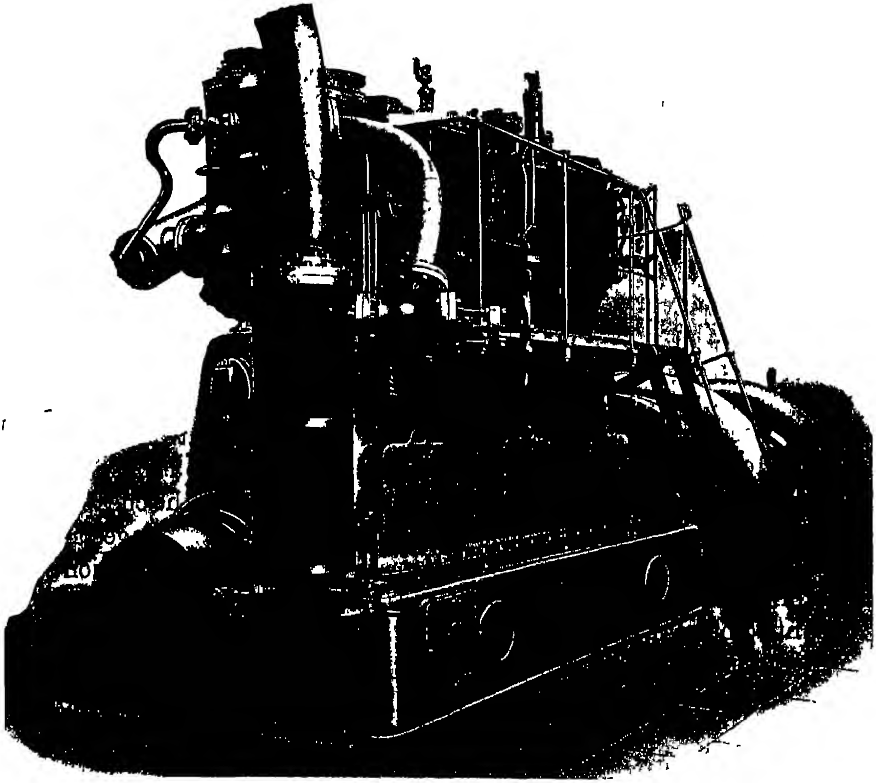


FIG. 16.—850 Horse-power "Sentinel" Triple-Expansion Steam Engine.

and glands are readily accessible, as is shown by Fig. 13. The makers strongly warn users against the temptation to speeding-up an enclosed engine, especially when direct driving a dynamo. The stresses increase as the *square* of the revolutions; hence in an engine running at 600 revolutions per minute the stresses are two and a quarter times as great as when the same machine is running at 400 revolutions.

Fig. 14 shows a very handy "Sentinel Junior" suitable for driving fans for ventilation. This arrangement of engine is suited for any purpose where a governor is not required.

Fig. 15 shows a "Sentinel" high-speed engine, of the compound double-acting forced lubrication type. This engine is in extensive use for the generation of electric light and power in factories, and also for belt or rope drive It is suitable for 100 to 180 lb. steam pressures, condensing or non-condensing—a thoroughly economical engine, steady in running, well governed, and of excellent workmanship.

Fig. 16 shows an 850 horse-power "Sentinel" engine, triple expansion, double-acting type, direct driving balancing dynamos for lighting work, suitable for 140 to 200 lb. steam pressure—a very suitable engine for a large establishment.

The Steam Turbine.

In many large chemical works, and in the allied industries, it is necessary to make provision for the supply of very considerable volumes of electric current, and in the equipment of the power-house the steam turbine is receiving close attention. The steam turbine in a practical form was first introduced by the Hon. C. A. Parsons in 1884, and since that time it has been continually improved, until it now holds first place as the cheapest and best generator of electricity. Its principal advantages are the low first cost; the small space occupied; rapid erection; minimum cost of upkeep and repairs; the small cost of lubricants (the makers claim that while the cost of oil for a reciprocating engine is 7 to 10 per cent of that of the coal, for a steam turbine the figure is only ½ to 2 per cent); the absence of cylinder lubrication, enabling the use of the exhaust steam, particularly in chemical works, for process operations; the absence of vibration; the small attendance required, one man being able to look after several large turbines; the excellent governing; even turning and good parallel running; while priming of the boilers (a very serious matter with an ordinary engine) has no effect on the turbine beyond slightly reducing the speed; while overloading can be indulged in to any reasonable extent.

These advantages are so great that where the erection of a large power-house is under consideration the claims of the steam

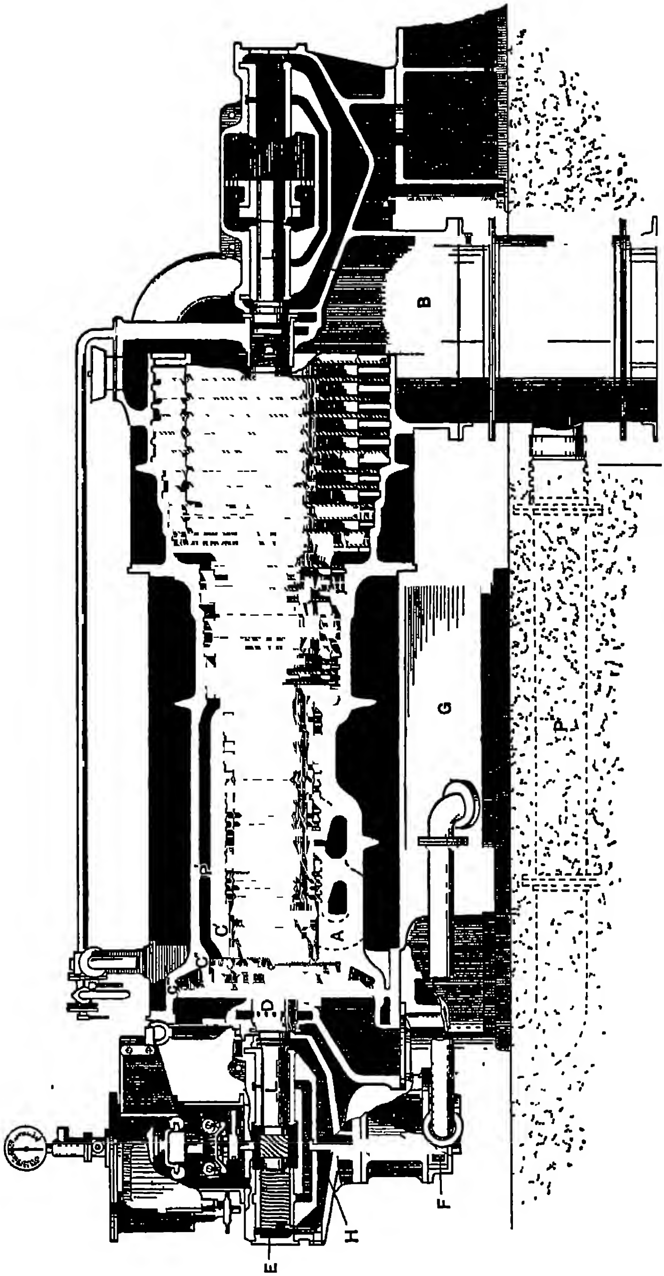


FIG. 17.—Section through Parsons' Steam Turbine.

turbine call for close examination. In this chapter the authors have been enabled, by the courtesy of Messrs. C. A. Parsons & Co., of Heaton Works, Newcastle-on-Tyne, to include a full description, with illustrations, of some of the principal types of the apparatus.

In its simplest form the steam turbine may consist of one or more nozzles which direct jets of steam tangentially on to suitable buckets or blades mounted on a ring or wheel; this form is termed the impulse type of steam turbine. Or it may consist of one or more nozzles carried on an arm or disc pivoted at the centre, the steam issuing tangentially from the nozzles and by its reaction causing the disc to rotate; this latter is the reaction type of turbine. In the Parsons' compound steam turbine both

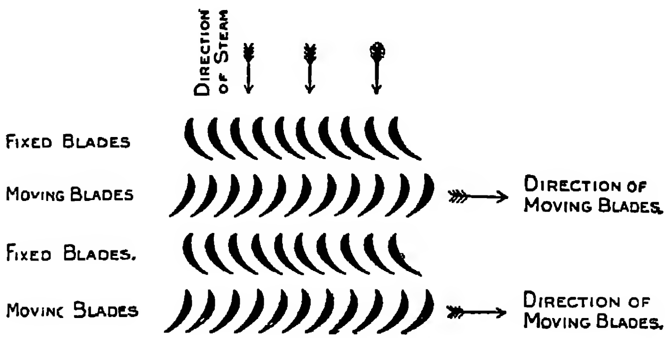


Fig. 18.

these types are combined, the turbine consisting of alternate rows of fixed and moving blades, each set of fixed and moving blades being like a simple turbine complete in itself.

On entering the cylinder the steam passes through the first row of fixed guide blades, which direct it in a number of streams in a tangential direction on to the first row of moving blades, thus imparting to them a rotational force due to the impact of the steam. The curved shape of the passage through the blades reverses the direction of the steam, so that it issues from the moving blades tangentially but in the opposite direction, and by its reaction imparts additional rotational force to the moving blades. The steam then reaches the next row of fixed and moving blades, where a similar operation takes place at each. The energy to give the steam its high rotational force at each

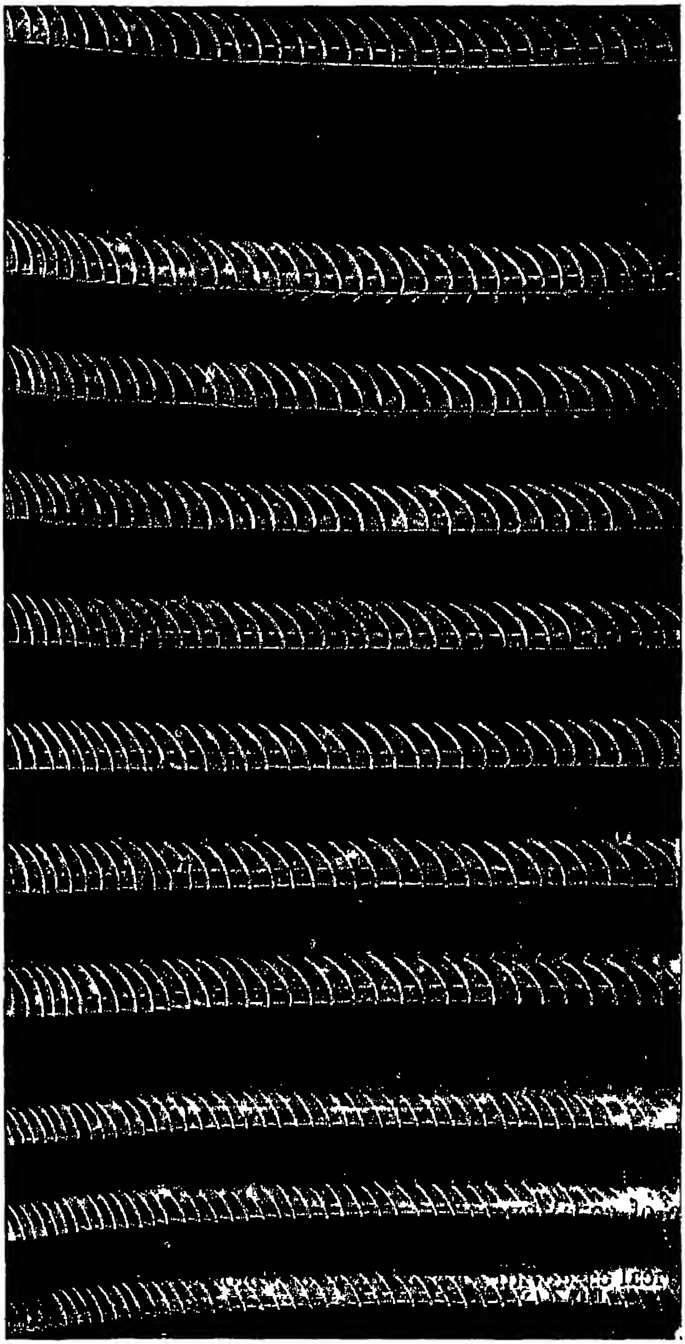


Fig. 19.—Blades in Cylinder of Parsons' Steam Turbine.

successive row of blades is supplied by the drop in pressure, the steam expanding gradually by small increments.

With regard to the economy of space which it is possible to effect by the use of the steam turbine, Fig. 20 shows this saving in an installation of turbo-blowing engine and condenser,

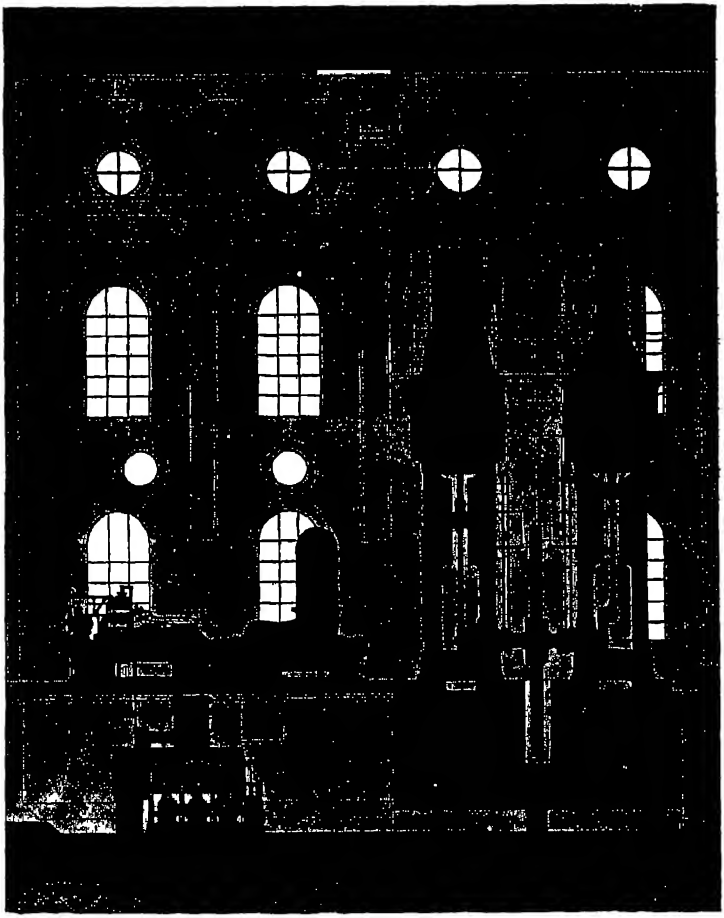


FIG. 20A.—Showing the Saving of Space Effected by Steam Turbine.

where the superiority of the turbine over the reciprocating engine of equal output is very evident.

The steam turbine which is shown in Fig. 17 consists of a cylindrical case with rows of inwardly projecting blades, within which revolves a concentric shaft with rows of outwardly pro-

jecting blades. The steam enters at A on the lower half of the cylinder, thus leaving the upper half quite clear of steam pipes and all obstructions, and facilitating dismantling. It then passes successively through the different rows of fixed and moving blades as explained above, and leaves the cylinder

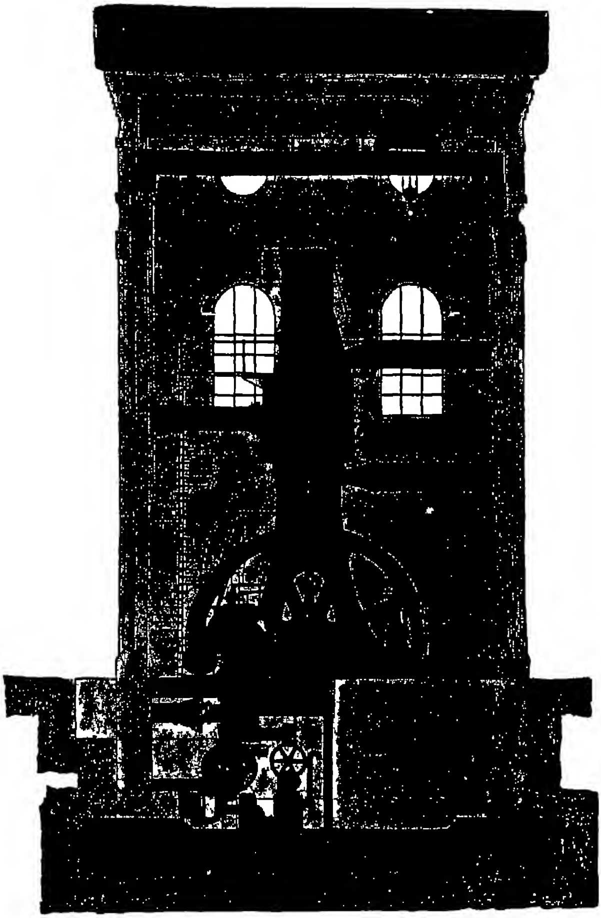


FIG. 20B.—Showing the Saving of Space Effected by Steam Turbine

through the exhaust pipe B. In order to give increased passage way for the steam as it expands, the shaft is made with three steps of different diameter, the heights of the blades being also increased.

The steam, in addition to its rotational force, exerts a pres-

sure endways along the shaft on the surface of the blades and the shoulder of the shaft This is balanced by the dummy pistons C′ C″ C‴, as shown in the section. They are made of diameters corresponding to the different parts of the turbine they balance, and are supplied with the corresponding steam pressure through the pipes P′ P″ The shaft thus runs in complete balance endways, and can be moved backwards and forwards with a light lever even when the turbine is running under full load. In order to prevent steam leakage, grooves are turned in these pistons, into which project, without, however, touching the moving parts, suitably shaped strips of brass caulked into grooves in the cylinder. The whole form a labyrinthine passage offering great resistance to the escape of the steam, most of which is carried round and round by the skin friction of the dummy pistons, producing a most effective screen against leakage. The two glands D, where the shaft leaves the turbine casing, are constructed in precisely the same manner. The steam for packing them is obtained from the exhaust of the steam relay, a live steam connection being fitted for use before starting up. An ejector is also fitted to draw the excess steam away from the glands.

The coupling between the turbine and generator is of the flexible claw type, to allow for slight differences in alignment of the two portions of the plant. The thrust block E at the end of the turbine shaft merely keeps it in place, with the right clearance between the fixed and moving parts of the glands and dummies, and adjustment is made in a few minutes with a small liner behind the thrust block. The shafts themselves are solid steel forgings in the smaller sizes, while in the larger sizes they are built up of hollow steel drums machined inside and outside, and then carefully shrunk together and pinned.

The blades are composed of a special brass alloy which long experience has proved to be the most suitable. This is rolled and drawn to the required section, and highly polished so as to ensure the friction with the steam being as little as possible. For the first few rows of blades, copper is used instead of brass, as being more suitable for superheated steam As will be seen from Fig. 18, the tips of the blades are thinned, so that in the case of their touching, the ends are merely ground away or slightly bent over. This improvement has been found to afford

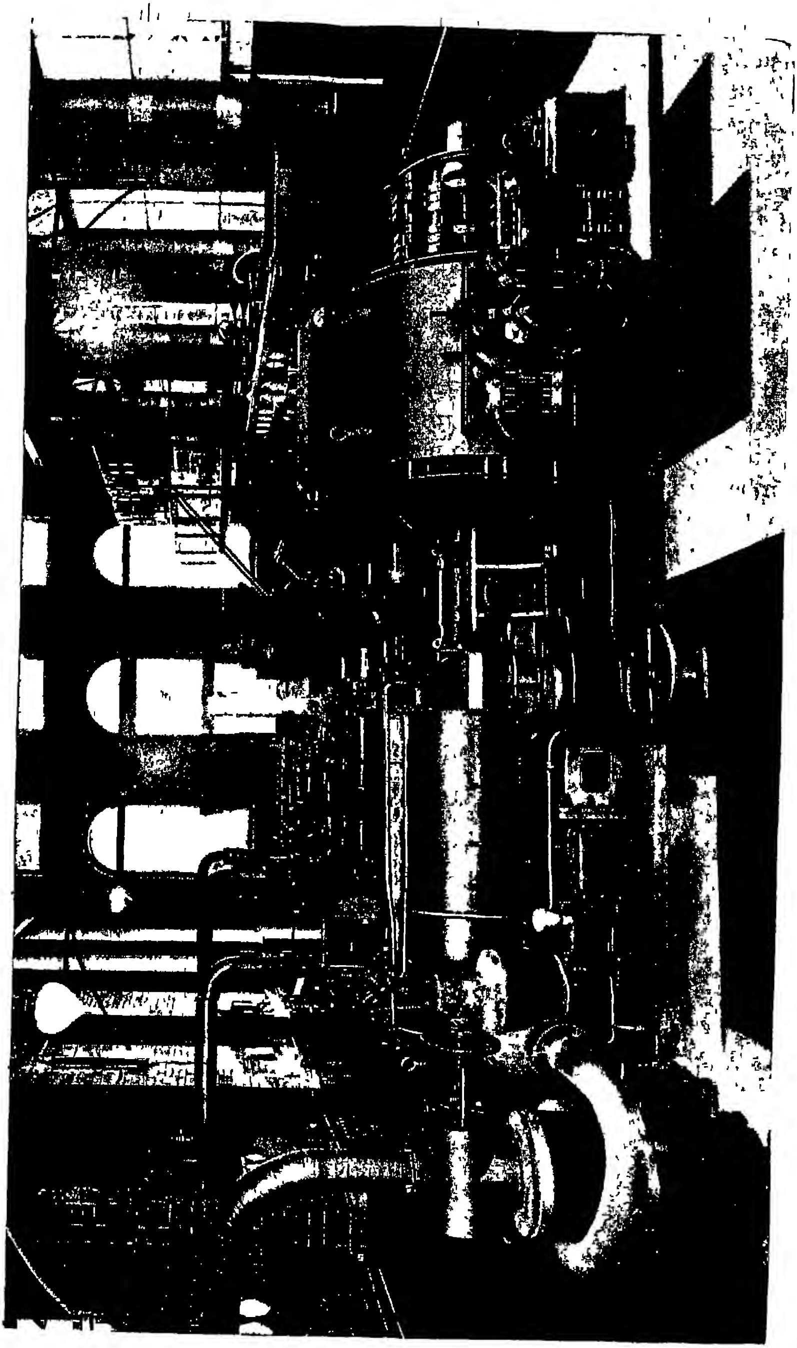


Fig. 21.—Parsons' Steam Turbine Installation: one 400 and three 200 K. W Direct Current Turbo-Generators.

additional security without at the same time affecting the steam consumption.

For many years past the blades have been caulked one by one into grooves in the cylinder and shaft, a method which has proved satisfactory. Messrs. C. A. Parsons & Co., however, have devised, and are now using, several methods of assembling and holding the blades in complete sectors of suitable lengths ready for insertion in the cylinder and spindle. These sectors can all be prepared beforehand and kept ready in stock, so that the actual operation of fixing the blades in the grooves of the cylinder and spindle is done very quickly. In one form the root strip is made a continuous comb, into which the blades are inserted; the teeth of the comb are then squeezed down tight one by one in a suitable automatic machine, and the whole is then bent to the required curvature to fit the spindle or cylinder. The sector goes into a dovetailed groove and is fixed then with a caulking strip. In another form, applicable also to existing turbines which have been already bladed by the older method, the standard blades and packing pieces are provided with holes by which they are strung on a wire of suitable section; they are then driven up tight in a former curved to the right radius for the part of the cylinder which they have to fit; the ends of the sector being secured by riveting or any other suitable method. The complete sector is then ready for fixing in the turbine by caulking in the usual manner In all these methods the full strength of the blade is maintained unimpaired right into the root fixing, there being no swaging or spreading out of the root or possible cracking of the metal, while at the same time the hold on the root is so firm that there is no fear of the blades coming loose.

The whole of the lubrication of the bearings, thrust block, worm, and governor gear, etc , is automatic, the oil being drawn by the pump F from the tank G. This pump is of the rotary type, consisting of two wheels gearing into one another, which sweep the oil under considerable pressure round the outer part of the casing It is placed low down, so that it is constantly flooded, and since it has no valves and is driven by a prolongation of the governor shaft, its failure is practically impossible. For flooding the bearings before starting up an additional small hand-pump is fitted. A cooler is also provided to reduce the tempera-

ture of the oil. Since there are no rubbing contacts inside the cylinder, no lubrication is required there, a fact which can be appreciated by those who realize the troubles of lubricating the cylinder and piston rods of ordinary engines, especially when running with superheated steam. As the same oil is circulated over and over again by the pump, and since no lubrication is required in the cylinder, the total consumption of oil is exceedingly small, and this has a considerable effect in the cost of generation in a large station. In a plant where a 1000 h.p. blowing engine has been running for three years, the total cost of lubrication averages 1s. 9d. per week, and similar plants elsewhere have given equally good results.

The governors themselves are of the centrifugal type, with the springs acting directly between the balls, and are both mounted on the same spindle H, driven off the main turbine shaft by worm and worm-wheel. Steam is admitted to the turbine in a series of gusts by the periodic opening and closing of a doublebeat valve, operated by a steam relay in mechanical connection with the turbine shaft, the duration of each gust being regulated by the position of the governor balls and collar. One end of the governor lever controls the plunger valve of the steam relay, and the other end is furnished with a small roller, which runs on the collar of the governor. This collar has one side higher than the other, and as it turns round, raises and lowers the end of the governor lever, and thus gives the periodic motion to the valve. For hand adjustment of speed, a separate collar, spring, and lever are fitted to the governor In addition, a runaway valve is also fitted, being held open against a spring by a catch and double trigger arrangement, so designed as to reduce pressure on the point of the catch to a minimum. In this way the release of the valve takes very little force and is extremely regular in its action, always cutting out at the speed for which it is set There is also a lever provided, by which the valve can be tripped by hand.

The work done by the governor itself is merely a slight alteration of the mean position of the lever end, and the relay plunger attached to it, the amount of travel remaining constant. The volume also of steam in the turbine is comparatively small, and passes very quickly through to the exhaust, so that the turbine itself responds at once to the governor, and the energy

stored up in the rotating parts being large, the variations in speed, momentary and permanent, are very small.

The turbine can efficiently expand the steam to a very high degree. To secure the greatest efficiency, the condenser should be so designed that the temperature of the circulating water when it leaves the condenser is as close as possible to that corresponding to the vacuum obtained; the subject of condensing plant and the proper distribution of steam in the condenser has been closely studied at Heaton Works with this end in view, and more than 150 condensers have been supplied giving most excellent results. In many cases it has been found desirable to increase the volume of circulating water and also its velocity through the tubes of the condenser This entails a larger motor for the circulating pump, but the total extra power required will not exceed 1½ per cent of the full output of the generator. The vacuum is 27·5 inches to 28 inches, with cooling water at 70° F., instead of a vacuum of 26 inches to 27 inches, which would be usual under ordinary conditions. The net gain in steam consumption, after deducting the extra power required by the motor, is 4 per cent to 5 per cent, without any increase in the size of the condenser.

In order to further improve the vacuum, the vacuum augmentor (Fig. 23) has been introduced. This apparatus consists of a steam jet ejector which is placed in the pipe between the condenser and the air-pump and draws the air and vapour away from the condenser, delivering it to the air-pump, the vacuum being much improved. By the augmentor the air and vapour are compressed to one-fourth of their volume, and are delivered through a small auxiliary condenser (where they are cooled and the steam condensed) to the main air-pump. The condensed water from the main condenser flows directly to the air-pump suction by a separate pipe which is water-sealed. The consumption of steam by the jet is only about 1 to 1½ per cent of the total steam required by the turbine at full load, and the net extra gain in steam consumption is about 5 per cent.

In many cases where engines are running non-condensing, an exhaust steam turbine (Fig 22) can be installed with advantage, if any water is available for condensing The work obtained from the steam will practically be doubled, and there will be no actual loss of water even if cooling towers are used,

FIG. 23.—Exhaust Steam Turbine (C. A. Parsons & Co.).

for the water lost by evaporation under ordinary conditions is only 80 per cent of that condensed. A steam accumulator will only be required where the supply of steam is intermittent, and Messrs. C. A. Parsons & Co. have an agreement with Professor Rateau for the supply of his type of regenerative thermal accumulator whenever required. The exhaust steam turbine can

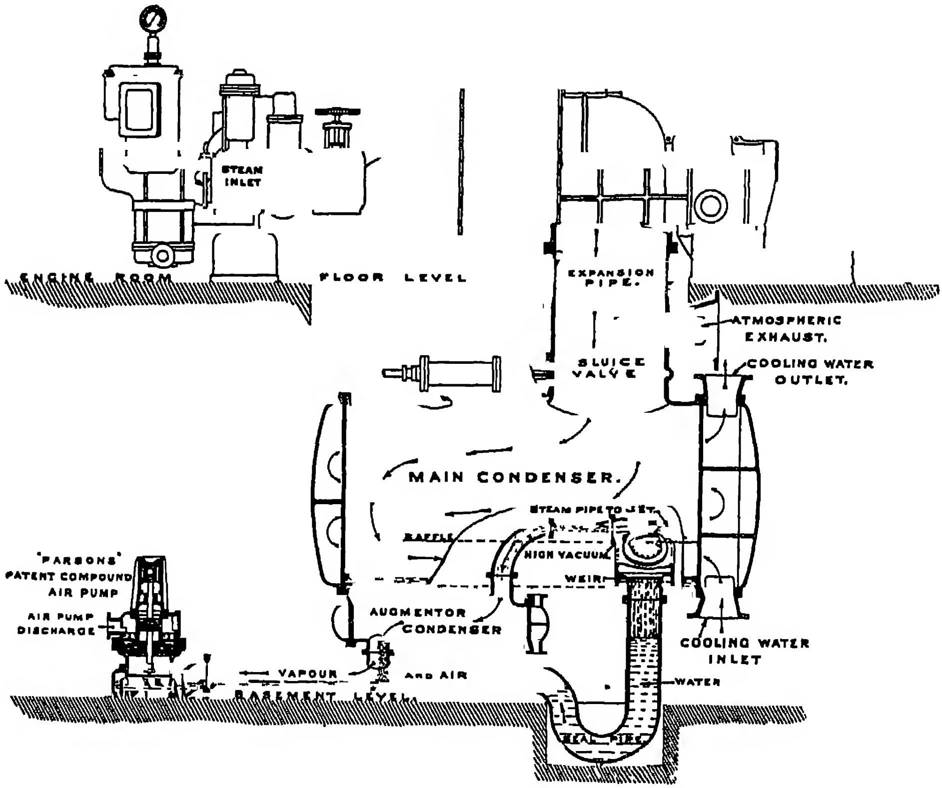


FIG. 23.—Parsons' Vacuum Augmentor.

drive any of the different types of machinery usually driven by the steam turbine of the ordinary type.

ELECTRICAL FITTINGS.

Where electrolytic processes are in use, the power required for these must be taken into account in fixing the size of the generating plant to be laid down, as in our former remarks we have only included generating power for motors and lighting.

It is the custom to carry the main cable from the generating station to a main distribution board, situated in the most convenient part of the works, and at as short a distance as possible, for sub-distribution to other distribution boards. In this way it will at once be apparent that the cable leading to the first distribution board must be sufficiently large to carry current for subdivision to the other points from which current is taken, and that it is much easier to carry cables of a small size to the different units than to carry larger cables direct. Bearing in mind the fact that fuses and switches should be so placed as to be easy of access, it must also be kept in view that all electrical apparatus should be well protected from misuse. To ensure this it is advisable that notices forbidding unauthorized persons to handle the various electrical apparatus be posted wherever the switches are fixed.

The Ingrey Automatic Weighing Machine.

A very useful apparatus which will find application in many large works is the Ingrey automatic weighing and recording machine The advantage of having the weight of bulk material automatically recorded during the loading or unloading of a barge or vessel is obvious, and an equally advantageous application is that of automatically recording the weight of coal fed into the hoppers of boilers. The Ingrey machine, as made by the Klein Engineering Company (1908), Limited, of 94 Market Street, Manchester, is shown in Figs. 8, 9, and 10.

The machine illustrated in Fig. 8 is arranged for weighing and recording the weight of a load when delivered to it by a "grab" or "skip" from a crane, and is specially applicable when the coal or other material is brought by barge or vessel alongside a wharf. The apparatus is quite automatic in its action, the weight or impact of any load setting it into operation and indicating upon a dial not only the weight of the individual load but recording and adding the weights up to 100,000 tons, after reaching which the recorder commences afresh at zero.

This machine does not deal with any predetermined load, but indicates and records the weight of each delivery, no matter how much this may vary. When a "grab" is employed the quantity grasped is very unequal.

The recording apparatus is contained in a dust-proof case,

and can be fixed in a locked cabin with glass doors for inspection purposes. Machines of greater or less capacity can be supplied,

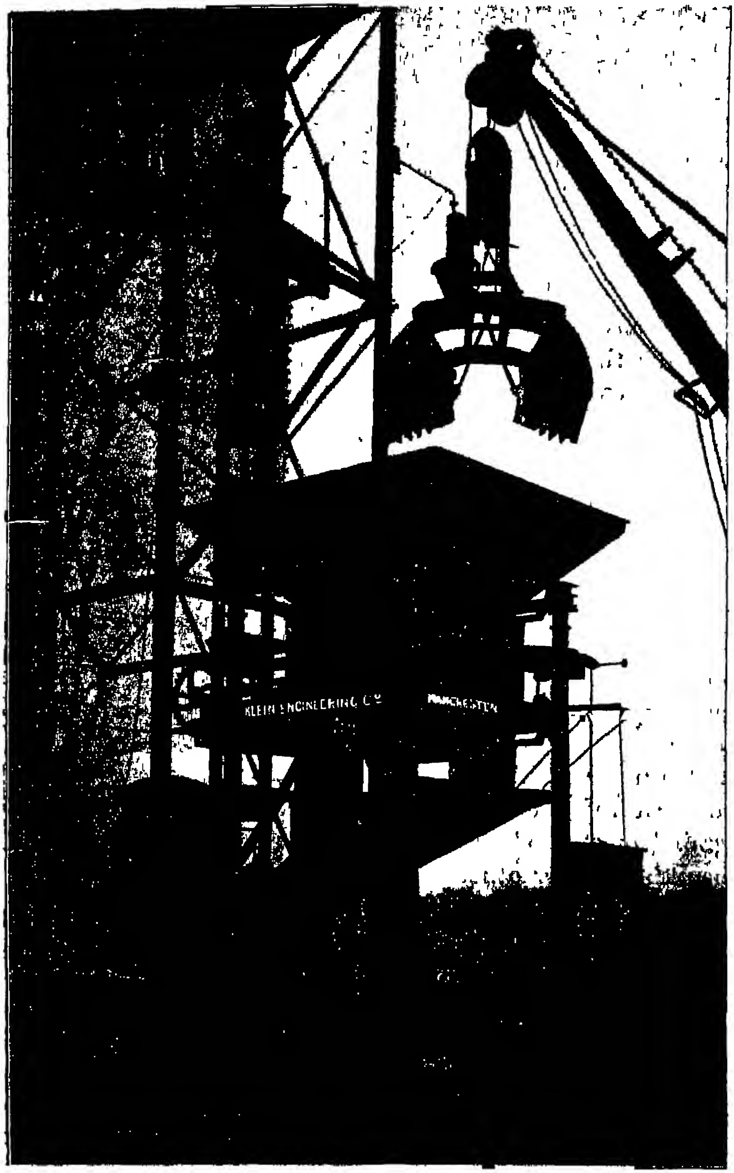


FIG. 8.—The Ingrey Automatic Weighing and Recording Machine.

and the speed of operating can be varied to suit any special requirements.

An important feature of this machine is that when receiving and discharging its load the weigh-bucket is raised clear of the knife edges, so that the vibration caused by the discharge from the grab operating doors, etc., is not communicated to the indicating and recording mechanism.

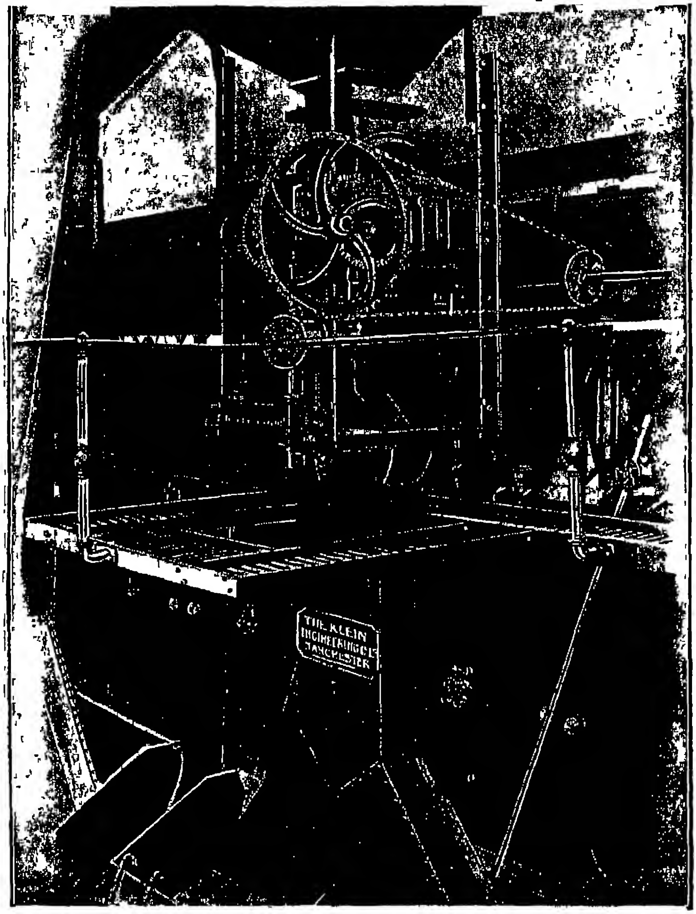


FIG. 9.—The Ingrey Automatic Weighing Machine Stationary Type

The Ingrey machine is now very extensively adopted where mechanically-stoked boilers are employed (Fig. 9). It is usually driven by chain gear from the stoker shaft, and the power required is very small In connection with this machine a special measuring valve or drum is preferably used.

Normally the machine remains out of action, but directly a supply of coal is required for the boiler a clutch is thrown into

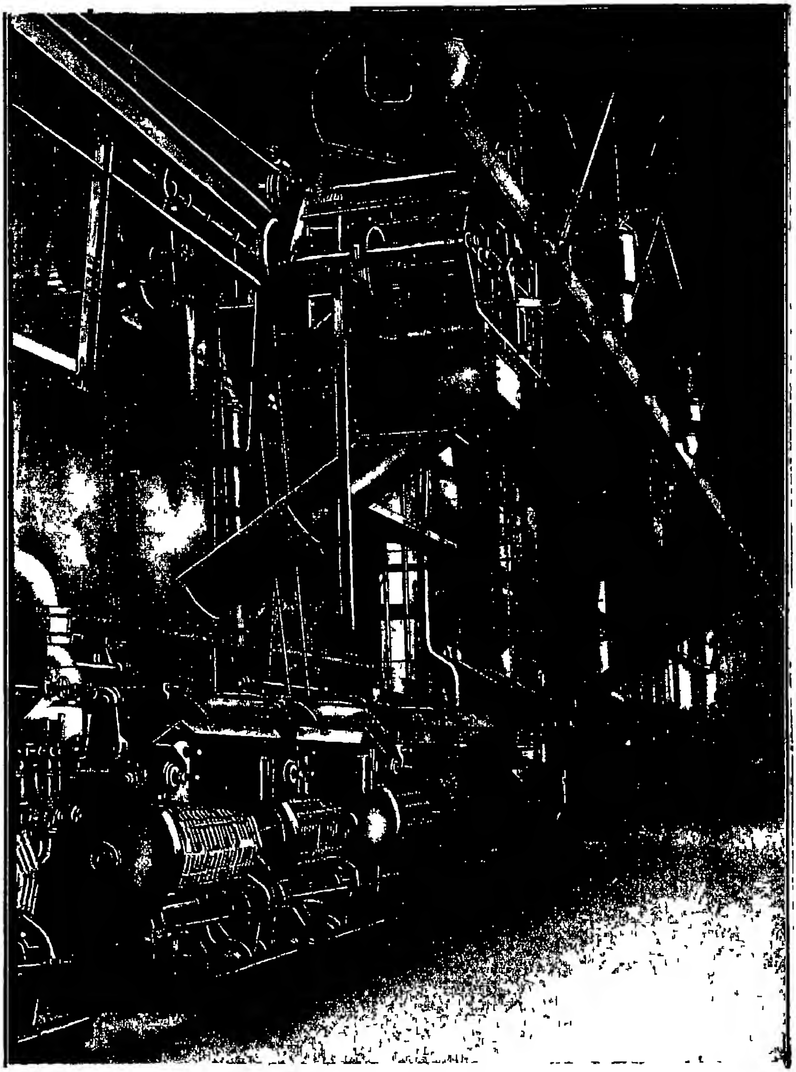


FIG. 10.—The Ingrey Automatic Weighing Machine · Travelling Type.

gear and the actuating shaft of the machine is caused to make one complete revolution. The first action is to move the measuring drum, which discharges its load into the weigh-bucket. In

the second action the bucket is lowered gently on to the weighing centres, and the weight of the load is transmitted to the recorder, which indicates the weight, and adds this to the total. The third action restores the bucket to its normal rigid condition, and, opening the door, delivers the weighed coal to a shute and thence to the boiler. The door automatically closes, and the machine throws itself out of gear and awaits a further demand.

This machine may be started into operation by the pulling of a cord or chain, but by an ingenious contrivance even this may be dispensed with, and the boiler is practically caused to help itself when it requires a supply of coal. Where two stoker-hoppers are attached to each boiler, the shutes from the machines are bifurcated, as shown in the illustration.

The advantages of a machine of this description are manifest, as by its use the exact quantity of coal consumed by the boiler is at any time easily ascertainable, and where a range of boilers is employed, useful comparisons can be made, and the blame for over-consumption rightly apportioned.

In some cases where a large range of boilers is in use, the machines are made capable of travelling upon overhead rails, so that one machine may be made to serve several boilers. Fig. 10 shows such an arrangement which is installed at an important power station. These machines do good work, but are much more expensive than the fixed type, and necessitate not only travelling gearing, but also the erection of a suspended gantry, whilst the advantage of knowing the actual consumption of coal of each particular boiler is not secured. It is obvious that the benefits attainable by adopting the one-boiler-one-machine principle are not here served. When this travelling form of machine is adopted, the automatic system of starting, *i.e.*, making the mechanical stoker determine when it requires coal, cannot be applied The starting in the case of the travelling machine must be performed by hand.

CHAPTER V.

SULPHURIC ACID PLANT.

In the arrangement of sulphuric acid plant it has become customary in recent years to arrange the chambers in sets of three. In the older works, chambers of largely varying dimensions may be found, whereas in modern works a chamber of moderate cross-section and length has become more usual Chambers of 20 feet width, 18 feet in height, and from 100 feet to 120 feet in length, are representative of this class. The width mentioned permits of easier construction than a chamber of greater width. As will be seen from the description and drawing (Plate III.) the timbers forming the roof supports for the leadwork of the chamber can be more readily obtained in lengths suitable for this width than where wider chambers are used

It has been the practice to erect the chamber platform at such a height as will enable the burners to be placed underneath, or, where the space underneath the chambers is not fully occupied by the burners or pyrites store, the height is still sufficient to admit of being utilized for many other purposes, and if of any advantage, a line of rails could be taken under, forming a covered shed for unloading goods.

Recent practice in the erection of chambers has brought iron and steel more into use as regards the columns and girders supporting the chamber platform It is only in the older works that brick or stone piers are to be met with for supporting the chambers, the smaller space taken up by an iron column being naturally a great advantage Opinions differ greatly as to the type of column to be used, some manufacturers preferring a circular column of cast-iron, or cast-iron of special section, or a steel column of I section, with suitable cap and base-plate riveted on, with angle-iron and gusset plates.

Assuming, then, that we are considering a plant consisting

of three chambers, each of which measures 120 feet by 20 feet, by 18 feet high, and allowing for a gangway between the chambers of 5 feet, and a further gangway outside the outer chambers of 3 feet 6 inches, we have a platform measuring 127 feet by 82 feet, and if the columns are spaced at 10 feet centres lengthwise of the chambers and 25 feet centres in the breadth, this would give a very suitable support for the main platform Our reason for suggesting a spacing of columns at 10 feet centres, lengthwise of the chambers, is, that this arrangement lends itself very well to the disposal of the burners, when these are placed underneath the chambers, as the usual width of burner front is 5 feet, by arranging the burners so that the jointing of the burner front plates comes opposite the centre of a column With this arrangement it will be found that in operating the burners the columns will not be in the way of the workmen in the operations of charging the burners or pokering.

The strength of the columns required will naturally depend on the weight which they have to carry, and although the chamber platform and chambers by themselves may not vary much in weight for a given size of chamber and thickness of lead used, the main weight will depend on the depth of upstand, which governs the acid contents the chambers will hold and determines the total load to be supported. Whichever column or type of column previously mentioned is adopted, a good base plate is essential, to spread the weight on the foundation. The foundations for the columns may be in concrete or brickwork, as shown in the drawing, but in all foundations where brickwork is used the bricks should be laid on the flat, and never on edge, and preferably "Metalline" bricks. If the columns are bolted down we prefer the bolt-heads to be below the level, so that the brick paving can be finished up neatly to the columns.

For a good working floor, in our opinion, nothing is better than bricks on edge, laid on concrete. Bricks laid in this way do not readily pull up with the use of shovels, rakes, or other tools used in connection with the firing of the kilns.

The chambers are seldom now roofed in, as the leadwork of the top forms the roof, and the central gangways and sides are covered by a small pitched roof, which is often covered with felt or thin sheet-lead. A bratticing is carried down from the sloping roof of the outside gangways to the chamber platform, with

open spaces of about half an inch between the boards. In some cases close boarding is preferred, and sliding windows are provided at a suitable height and distances along the outer gangways.

Where the leadwork of the top of the chambers forms the roof of these, it is customary to make one side of the chamber a foot higher than the other, so as to form a good drainage for the rain-water.

Running the whole length of the top of the chambers, and spaced at equal distances apart, it is usual to fix a couple of gangways, which are easily formed by two 9-inch planks placed side by side. These gangways are convenient for examining the top of the chambers and operating the lutes or attending to the observation glasses on the chamber top.

As will be seen from the drawings, the leadwork forming the top of the chamber is supported by lead straps from the transverse joists running across the chambers, and though we prefer the lead strap to embrace the joists completely and to be burned on to the leadwork of the chamber top on either side, the method shown in Plate III. is often met with, on account of the saving effected in the quantity of lead used. But where this method is employed, in our opinion, the straps are far more liable to be torn off, and the alternative method, where the strap entirely embraces the joist, is preferable. In this latter case it will be noticed that no nails are necessary, whereas in the former system it is usual to secure the strap with three nails, one at the apex of the triangle and two at a lower point spread apart. In this latter method, in order to equalize the support of the lead strap, the system is adopted of staggering these straps, so that the first one will be on one side of the joist and the next one on the other side of the joist, and so on alternately.

Although the lead top of the chamber will sag a little, however well supported, where attached to the crowntree, this is not sufficient in our opinion to warrant the insertion of lead draining pipes, which in some chambers are placed at intervals through the top sheet and out at the side sheets. The inclination of the roof-top should leave very little water to lodge at this depression.

The acid connections from chamber to chamber can be made either by means of a pipe and plugs, as shown in the sketch (Plate III), or by an open channel crossing the gangways. We

prefer the former method, as any obstruction in the gangway is an objectionable feature. The pipe if of ample size is not easily stopped up. If the system that we give later on, in cases of chambers of greater depth than we have been referring to (which have only an 18-inch upstand), is adopted, then the open trough would be below the chamber platform, and so leave the gangway clear, and in that way would not be objectionable.

The method shown of the pipe and plug arrangement is also suitable where the acid is run off from the chamber to other portions of the plant, to the acid tanks, or for immediate use.

The other fittings of the chambers will be considered separately as regards their uses and positions. The gas trunk connection from chamber to chamber is placed at such a height as to leave clear head-room underneath, and can either come out at the end of the sides of alternate chambers, or, if preferable, at a central position at the extreme end of the chambers. A preference obtains amongst some manufacturers for a circular gas connection, the idea being that with a flue of rectangular dimensions condensation is apt to take place and corrosion ensue at the square corners. We do not think there is much in this argument, but any disadvantage is readily overcome by using a U-shaped connection. This form is more easily made, and keeps its shape better than the circular trunk.

It will be noticed that where the gas trunk enters the chamber a greater width is necessary between the uprights of the chamber. To compensate for this, the uprights on either side of the gas trunks should be of stronger construction, and diagonal struts should be taken up to the underside of the crowntree.

Before the leadwork forming the bottom of the chamber is laid, it is very essential that the floor of the chamber platform should be left quite smooth and even, especially where the planks forming the chamber bottom come together, and no nails or any excrescence such as a hard knot should be left standing up. Attention to such details will do much to prevent the lead from being cut by pressure on any of these causes of abrasion. These are points which the contractor accustomed to this class of work should of course watch for himself, but those who are responsible for the future welfare of the plant will do well not to lose sight of them.

The best positions for the denitrating and absorbing towers are at one end of the chambers. The platform of the chambers is reached by a flight of stairs, preferably arranged in a double flight, with a landing in the middle, as one long flight is not only awkward to deal with, but is also very tiring to those who have to use it. Wherever possible, the means of operating any process should be made as easy as possible for the workmen, where the slight modifications from conventional design do not add materially to the expense of construction. While touching on this point, it may be mentioned that all stairs should, whenever possible, be carried up at an angle of 45 degrees, as accidents are far less likely to occur with an easy ascent than with a steep one. Moreover, where any acid or other corrosive liquid is likely to be spilt on stairs, this is more readily brought into contact with the legs or clothing of the person ascending steps with a steep inclination. Wide treads should be given, wherever possible, in preference to treads of narrow width. By observing little details of this nature as regards construction, increased comfort of working is secured.

In some works where three chambers form a set, the burners occupy a central position under the middle chamber, for the purpose of giving ample room on either side for the storage of pyrites and the handling of the residues from the burners. This arrangement also brings the Gay-Lussac and Glover towers close together, the centre-line of the Glover being a continuation of the centre line of the burners. It is immaterial upon which side of the Glover the Gay-Lussac is placed, but this, again, may be a continuation of the centre line of either of the outside chambers With this arrangement, the exit gas flue from the last of the chamber set will have to take a diagonal course to the Gay-Lussac, and if the selected arrangement is to place the burners centrally underneath one of the outer chambers, the Glover being also on the same centre line, then the Gay-Lussac would thus be thrown to a position on the centre line of the other outside chamber. There is not much to favour one or other of these arrangements as far as preference is concerned, but they are important points to be considered, as the disposition of other parts of the plant naturally depend on the position that these towers may occupy. Perhaps in the former case, where the towers are brought close together, the arrangement of the stairs

to the chambers and the tower lend themselves more conveniently to the general operations connected with attending to this part of the plant

The Glover Tower.

The construction of the Glover tower (Plate V.) has generally taken the form of dividing the weight of the tower proper and the house, so as to be independent of each other except with respect to the foundations, which are common to both. The tower itself is generally built up of a brick pedestal of acid-proof bricks, finished off neatly with cement, on which a lead apron is placed and beaten down to a few inches in depth over the top of the brickwork. On this, again, the lead dish forming the upstand for the tower bottom is placed, and the brickwork forming the sides of the tower is built up from this point.

The height of the brick pedestal is fixed by the acid tanks and cooling arrangement to which it has to flow by gravity. The height of the lead portion of the tower is usually about 25 feet, and the tower in cross-section varies from 8 feet to 12 feet square.

The house in which are placed the acid tanks which feed the tower is supported on four timber legs, which have their base on stone, and rest on the main foundation of the tower. The house is generally made in two storeys, the upper of which contains the acid tanks, and the lower floor the distributing arrangement for supplying the acid feed The uprights or corner posts require to be of strong timber, and are usually of pitchpine, and of 10-inch to 12-inch square in cross-section. The construction is clearly shown in the drawing, and it will be noticed that besides supporting the house, the posts also take cross-supports at frequent intervals in the height of the tower, from which lead straps are secured and burned on to the lead sheets forming the tower sides. The lead for the sides of the tower requires to be much stronger than that for either the chambers or the Gay-Lussac In some plants the sides of the Glover towers have been made with thicker sheets towards the bottom part and thinner sheets in the upper portion, but as this complicates the lead-burning, without in our opinion adding much to the life of the plant, we think it better to use a lead of uniform thickness for the whole depth of the tower side sheets,

and one of 10 or 12lb. will be found to last well, the upstand or dish being of much thicker lead, generally 60lb.

Many plans have been devised for distributing the acid at the top of the tower, but although that which we are about to describe is one of the oldest forms, we think that it is still one of the best. In this arrangement, a lead dish is formed, dipping some 6 or 7 inches lower than the main floor of the first storey of the house, and in this dish are a number of lutes or cups, with short pipes arranged so as to give a good general distribution over the area of the interior of the tower. On opposite sides to each other is a lead cistern, divided up into a series of compartments, from which outflows formed of an open lead trough are led with a diminishing lip, to the lutes on the tower dish for supplying the acid to this latter. These acid distributors, or lead pianos, as they are sometimes termed, are fed from the overhead acid supply cisterns placed in the upper storey of the tower. The tower itself is built up of acid-proof bricks, the lower portion of the walls being 14 inches thick, and reduced to 9 inches in the upper portion. The lower part, which is required to support the packing, is arched over at a suitable height from the bottom of the upstand, and leaving ample room above where the burner pipe brings in the gases from the burners previous to these finding their way up through the packing of the tower.

The Buckley arch-block is extensively used as a ready means of supporting the packing and lessening the labour which would be entailed in building arches of brick. These blocks can now be obtained in several sizes suitable for making arches of 3 feet, 4 feet, and 5 feet span, forming a complete half-circle.

Whatever form of packing is used in the tower, it is the general practice to commence with a chequered course or two of "Metalline" bricks, and in some cases the "Metalline" brick packing is continued up the whole height of the tower. Various forms of special packings are now employed in preference to the older method of using hard coke.

The method of packing the towers used in the vitriol plant has changed considerably during recent years. In the old type of tower, acid-proof bricks were chiefly used, with the liquor trickling down the brick-packing, which was arranged in pigeon-

hole fashion. During recent years the tendency has been to substitute, for the brick packing, material shaped into solid or hollow balls, when solid pierced with holes, so as to utilise the insides as well as the outsides as contact surface.

By the use of such material, the output of the plant has been very largely increased, and the necessary height of the towers for any given chamber capacity is correspondingly reduced, whilst the cost of the new form of packing compares very favourably with that of the old-fashioned brickwork.

The inlet for the gases coming away from the pyrites burners to the Glover tower requires very careful manipulation. The gases generally enter by a cast-iron pipe, which is stemmed into a lead socket burned on to the lead side of the chamber. The burner pipe requires renewal from time to time, owing to the heavy wear from the corrosive nature of the burner gases, and it is protected by a brick lining; consequently the pipe needs to be of considerable size to allow of this.

We have drawn attention to the great difficulty experienced in finding a suitable lip for the overflow from the upstand of the Glover tower to the cooling apparatus. A lip that has recently been much recommended is that made of fused silica by the Thermal Syndicate, Ltd., of Wallsend-on-Tyne. A description of this will be found in the chapter on general plant.

The exit gases from the top of the Glover tower are taken by a lead trunk, similar to that shown in the drawing, to the first chamber of the series.

The acid supply to the chamber cisterns is either forced up by means of acid eggs, as in the older works, or by one or other of the various types of elevator, such as that of Kestner, which, when properly used, is one of the best means for elevating acids, and of which a description will be found in the general plant section.

The framework of the tower house, except as regards the floors, may be of a light nature. Sliding windows for ventilation and light should be placed on each side, and the roof can be covered with felt or thin lead, the latter for preference. An overflow from the acid cisterns should be taken down, either to the chambers or to the acid cisterns on the working floor In dealing with the chambers, we have already referred to the

advisability for the arrangement of the stairs being readily accessible to the chamber platform.

The Gay-Lussac Tower.

The Gay-Lussac tower is very similar in construction to the Glover tower, the exception being more as regards the dimensions and the thickness of the lead. The lead for the Gay-Lussac need not be more than 7 lb. The connection with the chamber is by means of a lead trunk, similar to that between the Glover and the first chamber A suitable height of tower for a plant such as that described would be 50 feet, with a cross-sectional area of 64 feet.

Overflows from the acid cisterns should be conducted down to the supply cisterns.

The exit gases are taken by a leaden trunk down to the ground level, where a testing arrangement is provided previous to the connection with the flue to the chimney.

The upstand in the case of the Gay-Lussac tower does not give any trouble as regards the outflow of the acid, as the liquid is in this case comparatively cool, and can flow away to the acid cisterns as it comes from the tower.

The arrangement of the stairs and gangways connected with the tower are similar to those of the Glover, and should have direct communication with the chamber platform in a similar way.

In both the Gay-Lussac and Glover towers, where the acid is forced up to the supply cisterns for feeding the towers, the acid enters a closed vessel, which has a vent-pipe connected with it to the open air, in order to break the force of the air which is delivered with the acid as it is forced up to this high level, and which, if blown direct into the supply cisterns, would cause the acid to splash over by the intense agitation which the force of the air would produce

The plugs used in the acid supply cisterns on the towers are similar to those employed in the chambers, but where an independent plug and connection is not provided as a means of emptying these cisterns to the low-level acid tanks on the ground floor, a branch connected with the supply to the towers should be made in order to attain this object when necessary.

As will be noticed in the drawings, the dishes of both the Glover and Gay-Lussac towers are supported by iron bars covered with lead, or tubular section is sometimes used in preference, as being lighter and more easily covered.

In describing the chambers we have already drawn attention to the desirability of the angle of the stairs being made as easy as possible, say not more than 45 degrees, and this must be borne in mind with regard to the stairs of both the Gay-Lussac and the Glover, even at the expense of introducing a secondary platform and making two flights of stairs instead of one continuous flight.

It will be noticed in the construction of both towers that the crosspieces between the towers not only act as supports to the leadwork, but also as distance-pieces between the tower legs, and are tightly drawn up by iron bolts through the tower legs immediately above or below these crosspieces.

The acid on leaving the Glover tower is exceedingly hot, and passes through a cooler before being run into one of the acid tanks for distribution in the system again. Various forms of cooler have been devised for this purpose; some being of the open type, which consists of a series of lead troughs, acid being run in one trough with water on the other side of it, the water running in the opposite direction to the acid Other forms of coolers are those in which the acid runs through a lead coil surrounded by cold water

A series of lead-lined tanks are necessary for containing the acid from the Glover and Gay-Lussac towers, and one for chamber acid. These will either be connected to acid eggs or Kestner elevators, for elevation and distribution to the several parts of the plant, as outlined in the brief general description of the process given below.

Notes on Vitriol Manufacture

It has been thought desirable, for the convenience of engineers who are not intimately acquainted with the chemistry of vitriol manufacture, to include a brief summary of the operations which are involved, and such a summary may be found useful by many who may have occasion to consult this volume. For details as to the theory of the process, reference may be had to the standard text-books on chemical technology.

Vitriol making consists in first roasting pyrites in specially constructed kilns or burners, with access of air, and producing sulphurous acid gas. The gas thus obtained passes by means of leaden trunks from the burners into the chambers, which in this country are usually oblong in shape, and constructed of lead sheets suspended on timber framework.

In their passage from the burners to the chambers the sulphurous acid gases pass up the Glover tower, down which weak "chamber" acid flows, this acid containing nitrous acid gases from the oxidizing process taking place in the chambers. The weak chamber acid is concentrated, and the nitrous gases are expelled and carried forward into the chambers for re-use as the oxidising agent in the process. In the older type of burners nitrate of soda and vitriol are placed in "nitre-pots," which pots are placed in a flue above the burner proper. The nitrous acid gas required for use in the chamber, to oxidize the sulphurous acid into sulphuric acid, is thus produced. In the latest type of vitriol plant the potting ovens or flues are not used, but liquid nitric acid is fed into the Glover tower. Reference to this and other modifications of working will be found elsewhere

From the Glover tower the burner gases pass into the first chamber of the series—a series generally consisting of three or four chambers, although in small plants two are sometimes sufficient for the output required.

The sulphurous acid gases from the Glover tower, containing the nitrous gases from the potting ovens (or the volatilized nitric acid if this is used in the liquid state), are mixed with steam, or, in the case of the latest practice, with water which is sprayed into the chamber. The sulphurous acid, nitrous acid, and water react, weak sulphurous acid is formed, and this collects on the floor of the chamber. The chambers are connected with the Glover tower and with each other by means of leaden trunks for the gases, and dishes or upstands for the vitriol, which passes from chamber to chamber of the series.

From the last chamber of the series the exit gases pass to the Gay-Lussac tower. This is also a lead-lined structure, filled with packing material, down which trickles strong acid from the Glover tower. This acid absorbs all the nitrous acid left in the exit gases from the process, and after this absorption the gases are draughted into the chimney. The strong nitrous

acid from the Gay-Lussac, together with the weak and nitrous chamber acid, is fed to the Glover tower for denitration, as already described.

In addition to the principal sections of the plant briefly mentioned above, various accessories are used. In modern plants fans are now employed to draw the gases through the whole system. Intermediate towers are also employed, which add to the capacity of the plant. For lifting the acid from the ground level to the tops of the towers either acid eggs, or automatic elevators, are used. In the former case the acid is blown up to the tanks on top of the towers by compressed air from a blowing engine, where automatic elevators are employed the process is much simpler; full particulars of the automatic elevators now in use will be found in the section on general plant

Recent Developments in Vitriol Plant Design and Working.

The general trend of development in Great Britain as regards the design and working of vitriol plant deserves careful consideration by those who may be contemplating the erection of new works, or the remodelling and bringing up to date of existing installations. The successful working out and application of the contact system on the Continent has had a remarkable effect in stimulating improvements in the older chamber system, which still holds the field in this country, and which, moreover, does not appear to be seriously threatened as regards the position which it occupies where the production of any but the highest strengths of vitriol are concerned.

In considering the recent developments in design and working, it must be remembered that the great bulk of the vitriol produced in this country is required for use in the manufacture of salt-cake in the Leblanc process, for the production of superphosphates, and for such purposes as the recovery of ammonia as sulphate from gas liquor. This being the case, the possibility of competition from the contact process does not enter into the question. The position in Germany is different. Very large quantities of high-strength acid are required for use in the early stages of the synthetic indigo manufacture, and it is here that the advantages of the contact system are manifest. The incen-

tive to research which has been provided by the working out of the new method, however, has benefited to a remarkable extent those manufacturers who depend for their supplies on the chamber plant, and to these a summary of recent practice will be of interest.

It may be observed at the outset that there is nothing which is distinctively new in the various modifications which are now being generally adopted in chamber vitriol plant. These modifications are more in the methods of working than in design, and, apart from the introduction of plate towers, involve only the addition to existing chamber plant of comparatively inexpensive accessories. The principal alterations were long ago indicated by such authorities as Lunge, and the progress which has been made is simply the result of careful experiment on lines which were already laid down by experts in the technology of the process.

In the following summary of developments in design and working, it may be observed that although a good many of the modifications have been much discussed, there is still the usual tendency on the part of the general body of vitriol manufacturers to keep to old methods and old types of plant. Chemical manufacturers in the main have always been noted for their reluctance to deviate from old and tried methods and apparatus, and much that has recently been written as to radical developments or modifications in vitriol plant does not apply to the average works where the chamber plant, in its unchanged form as erected ten, fifteen or twenty years ago, is still successfully operated.

Taking the various sections of the plant in their order of working, it may be noted that the hand-fed kiln continues to hold its place. Mechanical furnaces have not been so generally adopted as was anticipated, and it is acknowledged that their use does not compare very favourably with the old type of kiln, except in cases where wages are below a certain level. The pyrites used in mechanical burners must be small, necessitating finer crushing and producing much dust, to catch which, dust chambers may be required.

The old method of introducing the nitric acid into the chamber system, by generating it from nitrate of soda and vitriol in the nitre ovens of the pyrites kilns, is now falling into

disuse in many works. It is to be noticed that the modifications in working the chamber vitriol plant which are being most generally adopted are those which do not call for structural alterations in existing plant. Vitriol plant does not lend itself to extensive alterations after erection. The units of the plant are mostly built-up units, they are not easily altered, and consequently any modification, to be readily adopted, must be of such a nature as to be feasible without calling for extensive structural alteration.

Such a change can be effected in the method of introducing the requisite nitric acid. The generation of this in the old nitre pots does not lend itself to accurate control. The potting is an operation which is somewhat clumsy and wasteful, and consequently a simpler method has found favour with many vitriol makers. By feeding liquid nitric acid down the Glover tower the proportion of acid can be carefully controlled, potting is done away with, and economy of nitric acid is effected.

Much has been heard during recent years of radical alterations in the design of vitriol chambers, but here, again, the tendency in this country is certainly not in the direction of discarding the old design. The difficulties in the way of structural alterations to existing chambers are obvious. In Germany chambers have been erected which are tower-like in construction. The oblong form has been abandoned, and instead of chambers 120 feet long by about 20 feet in height, we find shorter and loftier structures. The cause for this modification is found in the theory that condensation is greatest where the burner gases have a longer vertical fall from entrance to outlet. Hence the tendency towards lofty chambers. But obviously this principle cannot be applied to existing chambers of the old type. That it is a sound theory seems to be borne out by the results of working in the "tower" chamber In these latter the tendency is to make the height greater than the length or width. Guttmann ("Journal of the Society of Chemical Industry," 1908, p. 667) mentions a rectangular chamber, which, as originally built with a height of 20 feet, worked at 14 cubic feet per ton of sulphur burned per twenty-four hours, has been rebuilt with a height of 40 feet, and now works at 11 cubic feet per ton of sulphur The gases led in at the top of the chamber travel slowly downwards, forming eddy currents; when the

height of the chamber is greatly increased, the length of the path of the gaseous currents is increased proportionately, and a greater period is allowed before the exit is reached.

Another modification which does not call for structural alterations is the use of fans for controlling the draught in the sytem In the old method of working, where the suction of the chimney was relied upon, the result was at times far from satisfactory. It has been found that by the use of specially constructed fans the draught can be kept under exact control and the output of the plant materially increased.

The same remarks as to the reluctance of manufacturers to adopt modifications which are of the nature of additions requiring structural alterations, applies to the introduction of the necessary moisture into the chambers. It was formerly the invariable rule to supply the requisite moisture by means of steam jets. This raised the temperature of the vitriol chambers, and as the result of experiment it has been found that if water is introduced in the form of a fine spray, the reaction temperature is kept down and the output of the chamber is greater. The substitution of water sprays in place of steam calls for a greater height of the chambers to ensure complete vaporization of the water before it reaches the bottom of the chamber. To secure this additional height, cones or cylinders have been added to the roof of existing chambers, the water spray being placed in the upper part of the cone.

Another modification is the introduction of plate towers between the chambers. This considerably increases the reaction surface, and much acid is condensed in the towers.

Glover towers composed of volvic lava blocks have been used on the Continent, but there is little likelihood that such a system will be extensively adopted in this country, as the cost of the blocks is too heavy to permit of their displacing the older forms of tower construction. The advantages which are claimed for these towers are that they can now be made to stand by themselves; that even if a thin outer shell of lead is used, the amount of lead required is less than in the old-form Glover; and that no timber structure is required, as feed-tanks can be dispensed with by the use of automatic elevating and feeding apparatus.

With regard to the Gay-Lussac tower, the use of automatic

acid elevators has simplified the feeding of this. It is now not an uncommon method to provide a central Glover tower to take the nitrous gases from several Gay-Lüssacs in the case of very large plants.

Circular chambers have been introduced, provided with interior vertical partitions in the form of spirals, so that the gases are compelled to pass through the chamber in spiral fashion. The partitions are made of porcelain, and may be perforated. The advantage claimed for these Meyer chambers is that a longer period of traverse is secured for the gases, and that greater condensing capacity is thus obtained. Meyer's tangential chambers are provided with two or more tangential inlet tubes at suitable distances apart and at different levels.

By the use of these various modifications it has been shown in practice that the yield of acid per cubic foot of chamber space can be very materially increased The increased output necessitates much greater care in working, and it follows that the labour charges will be higher. The question of the "life" of the "tower" chambers now being used in Germany has been discussed. The old-fashioned chamber, when not worked too hard, had a life which in some cases was as long as fifty years, whereas "tower" chambers worked on what may be termed the intensive system would probably not last for more than twenty years.

The outstanding result achieved by the introduction of these various modifications in the working of the old chamber process is that it is easily possible to increase the output of the plant by such means as water sprays, feeding of liquid nitric acid, the use of fans, etc., and this fact has done much to delay the introduction of the contact system into this country

CHAPTER VI.

HYDROCHLORIC ACID PLANT.

In dealing with hydrochloric acid plant, the first portion of the plant to be considered is that connected with the decomposition of the salt in the roaster, or salt-cake furnace The form of furnace that is now most generally used is that of the plus-pressure type. The advantage of this over the usual muffle furnace is that by placing the fireplace at a considerably lower level than the body of the furnace the gases coming away from the furnace have a tendency to leak into the muffle, instead of the gases from the muffle leaking into the flues. This will be more apparent on following the description of the furnace shown in Plate VI. The depth of the fireplace will be seen to be some 7 ft below the working-floor level of the salt-cake shed, and as the firing is done from the floor level, it is only necessary that the ash-pit which is sunk to the level mentioned below the floor line should be of sufficient size to give ready access to the ashes or for the renewal of the fire-bars, as the case may be A vertical cast-iron ladder should be built into the wall, for the purpose of getting down into this ash-pit.

It will be noticed that the fireplaces are built separately, and for the sake of strength the four sides of each fireplace are formed in the shape of an arch in plan, leaving a vertical airshaft between the two fireplaces to the full height of the furnace shaft. The fire-bars are at a convenient height above the ash-pit floor. and underneath the fire-bars air-holes pass through the side walls into the vertical air-shaft between the two furnaces The cast-iron ash-pan is supplied with water during the working of the furnace

The gases, on leaving the furnace shaft, pass over the top of the muffle to the rear end of the furnace, and there drop down to a series of flues running underneath the muffle to the

furnace end again, where they join in a flue which has a branch passing underneath the decomposing pan, or continuing direct on its way to the main flue leading to the chimney. If the heat is required underneath the decomposing pan the damper in the by-pass leading to the main flue is closed, and the one leading to the decomposing pan is open, or vice-versa. It will be observed that the pan is placed on one side of the furnace opposite to the side on which the charges are withdrawn from the muffle. A cast-iron pan of the type shown in the illustration is that in most general use, and the flange round the side is useful for taking up the thrust of the arched cover which is built over the top of the pot. The thickness of the pan bottom, it will be observed, is much greater than at the sides where it joins the flange, as this is the portion which has the most wear and tear, and is generally about 2½ inches thick

The setting of the pot requires a good deal of care in the arrangement for protecting it from the direct heat of the furnace. A common form of setting, and one which we can recommend, is to turn a pigeon-holed arch over the top of the flue conveying the gases from the furnace, and thus baffling the flame from striking directly on the bottom of the pot. The same effect can be obtained by fire-clay slabs built over the entrance for the gases, in such a manner that they strike the top covering blocks before finding their way to the underneath of the pot. The flue from the pot joins up to the main flue to the chimney, and is regulated by another damper. In some cases, further advantage is taken of the heat before the gases pass away into the main flue, by allowing them, after leaving the pot, to pass under a supplementary heater for the acid feeding the pot, in which case this heater occupies a position immediately behind the salt-cake pot, and with an arrangement so that the gases can either pass under it, or, by closing a damper, they may pass away to the main flue. In a furnace of the dimensions given in the drawing three doors for withdrawing the charges from the muffle are provided. The type of door which is most handy for this class of furnace is a balanced door which can be raised or lowered readily, the chain supporting the door passing over pulleys, with suitable counter-weights. The dead-plate forming the bottom of the door should be placed level with the floor of the muffle, and just within the door space an opening is formed

for the purpose of allowing the charges, when being withdrawn from the muffle, to drop down into the hopper which is placed under each doorway. These hoppers are usually made of wrought iron, and are partly built into recesses in the side wall of the furnace, and made with a slope, so that the doors of the hoppers, which are closed during the drawing of a charge from the furnace, will more readily fall to their frame than if placed in an upright position, the object of the hopper boxes being to protect the workmen from the fumes that are given off from the roasted salt-cake. In the older form of roaster the charge was raked out on to the floor, but in this form the cake drops into the hoppers, and the gas rises up through the aperture into the muffle.

The gases coming away from the muffle are in many cases conveyed by a separate pipe from the muffle and connected to condensing cisterns, as these gases are weaker than those coming away from the salt-cake pot. The flue taking the gases from the pot is taken from a point directly over the centre of the pot, and by means of pipes the gases are conveyed to another stone condensing cistern. These stone cisterns are used as a preliminary to the gases entering the towers where the main condensation takes place. The number of the condensing cisterns varies in many works, and in some cases where the towers are of very large area cisterns are dispensed with, but Lunge and other good authorities are in favour of their use.

The pipes used for conveying the hydrochloric acid gases are generally of earthenware, unglazed, thoroughly well boiled in coal tar, as, next to glass, these are found to resist the action of the condensed acid as well as any material, glass being far too expensive to use for this purpose, as well as being so liable to fracture.

The pipe-line connecting the salt-cake furnace with the cisterns should have a fall towards the cisterns, and the jointing material should not only surround the spigot end, but should also form a joint between the end of the pipe and the socket. In this way a firmer joint is made than where the spigot end of the pipe comes in direct contact with the socket of its neighbouring pipe, but the jointing material should be well cleared off from the inside of the pipe as each length is placed together. A timber runway is the handiest arrangement for supporting

the pipe connections, with cross-supports at intervals underneath each pipe.

The hydrochloric acid towers may next be considered. Owing to the nature of the acid dealt with, and also to the great weight which a tower of this description places on a small area of ground, the towers require very careful building. A stone foundation, built up with a jointing material of coal tar and sand mixed, forms as good an arrangement as any that has yet been tried, and a thick layer of asphaltum should form the top dressing. The height of the base of the tower, or pedestal, depends greatly on further processes connected with the use of the acid, as, for instance, where the Weldon process is in operation in an alkali works a height of 20 feet would not be too great, but where the acid itself is only required, 10 feet would probably be sufficient for running into further receptacles, such as supply cisterns.

The bottom of the tower is generally formed of one large stone, from 10 inches to a foot in thickness The tower is rectangular, and formed of carefully selected stones jointed as shown in the drawing. The stone slabs are further supported by a frame of timber and iron bolts, which tie the component parts together. The tower top is covered over with a stone, in which a series of lutes are formed, and through which the condensing water trickles over the packing material in the tower. The gases enter at the bottom of the tower, through an earthenware pipe carefully stemmed into an opening cut through one of the side stones, and above this inlet for about two feet is a clear space before the packing of the tower commences. The packing is supported by stone blocks spanning from side to side of the tower, or where the dimensions of the tower would throw too great a weight of packing on such supports, intermediate vertical supports are introduced, and spaces are left between these supports for the gases to escape up the tower and find their way through the packing to a clear space at the top of the tower.

Hard coke, as in the Gay-Lussac, has been generally used as a packing material for hydrochloric acid towers, but many of the other forms of packing material now on the market may safely be recommended. It will be remembered by many engaged in the alkali trade, that a serious accident occurred at one of the

Tyne works some years ago, when the packing of coke in a tower became dry and set on fire, resulting in the collapsing of the tower, fetching down with it one or two adjoining towers and entailing serious loss of life.

The tower woodwork is continued above the stonework top, so as to form a support for the water tank for flushing the tower. The tower top is reached by a series of stairs, with platforms at suitable distances. The exit for the gases is taken out from one of the side stones a little below the luted stone cover, with a sampling arrangement near the ground, for testing the gases before they enter the flue to the chimney.

A simple arrangement for flushing the tower, and one that is still much in use, is that of the tumbling trough. This is composed of a long trough, the full length of the tower top, placed in a central position, and divided in the centre longitudinally, forming a V-shaped trough on either side of this central division. The ends are pivoted, and the action is that the water, running on to one side of the central division, fills that side with water until it overcomes the equilibrium of the empty side, when the trough falls over and discharges its contents over the top of the tower. The other division is now filled up until such time as its weight reverses the action, the water supply being regulated by the tap feeding the trough

The water cistern at the top of the tower is similar in construction to those described in other sections.

Fig 27 shows a small plant by Messrs. Doulton & Co., Ltd., of Lambeth, for the condensation of the hydrochloric acid driven off in the salt-cake furnaces The gas from the pan and muffle are taken through separate fire-clay pipe-lines to small tar-boiled stone columns, in which considerable cooling is effected, the temperature of the gases on leaving the furnaces being much too high to permit of their being taken directly into the stoneware vessel

The gases pass through the receiver, batteries, and standpipes, to absorption towers of large capacity, which are ultimately connected to the chimney flues.

The towers are fed with water, which flows from the bottom of the tower to the receiver batteries, flowing from vessel to vessel through short glass tubes connecting the inlets made in the receiver for that purpose These inlets being placed about

the middle of each, the receivers hold a large quantity of acid, exposing a considerable surface for absorption, and the acid and

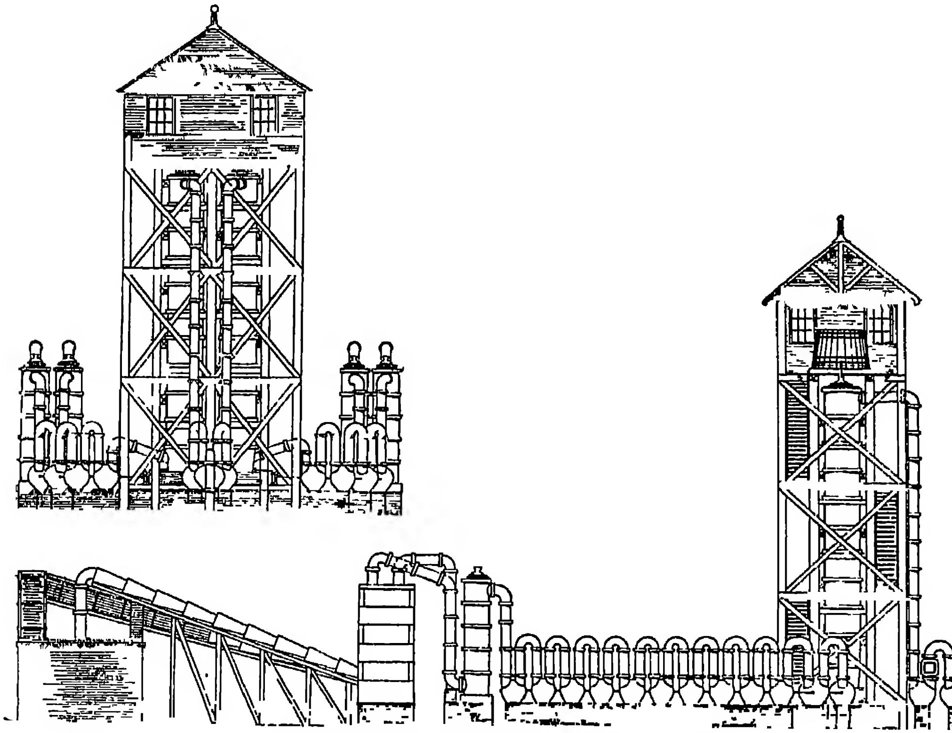


FIG 27.—Small-scale Hydrochloric Acid Plant.

gases travelling in opposite directions, the acid gradually increases in strength in its progress through the batteries.

CHAPTER VII.

NITRIC ACID PLANT.

In the nitric acid plant the chief feature is, of course, the stills. In many cases a house is devoted entirely to these, and this is especially the case in works designed for the manufacture of explosives.

A plant on the Valentiner system is illustrated in Plate VII. The stills, as will be seen, form a battery of six In this case the still itself consists of two parts; the cast-iron body, or receptacle, being made in one part and the cover forming a separate portion.

Provision is made on the floor level for running out the nitre-cake at the end of each operation, and the arrangement generally consists of a cast-iron trough running the whole length of the battery of stills, but at some distance from the still itself, as in this case it is customary to have an independent shute, which is operated by an overhead attachment, so that the shute can be placed underneath the spout of any one of the stills for discharging into the nitre-cake trough.

Many nitric-acid makers have experienced difficulty in breaking up the nitre-cake after it has set in the troughs, and to render this operation easier the troughs are sometimes made with a raised-up portion or rib, which partly divides the nitre-cake into separate cakes (slabs), which are more easy to manipulate.

We have seen arrangements of this plant, where the run-off troughs have been arranged outside the still-house, and this practice has undoubtedly certain advantages, but in any case a store is necessary for the nitre-cake, as it is not usual to work up this by-product on the spot. In the majority of works the practice is to store the nitre-cake and sell it to other manufacturers who are laid out to deal with it.

A quantity of acid drains away from the nitre-cake in the store, and it is, therefore, necessary that the store should be constructed of acid-resisting material to such a height as storage takes place. The floor should be laid with a fall towards a gutter leading to a mother-liquor well, from which the acid can be pumped up again for further use.

The still proper generally lasts much longer than the still-head or cover, in many cases three of these latter being required before the still itself has to be broken up. In some methods of setting the still, the wear and tear on the covers has been lessened by allowing the setting to be continued over the top of the cover, thus causing the heat to circulate round the cover as well as the still.

The gases coming from the still-head are passed through a worm which is immersed in a wooden tank with inlet for cold water, and provided with overflow.

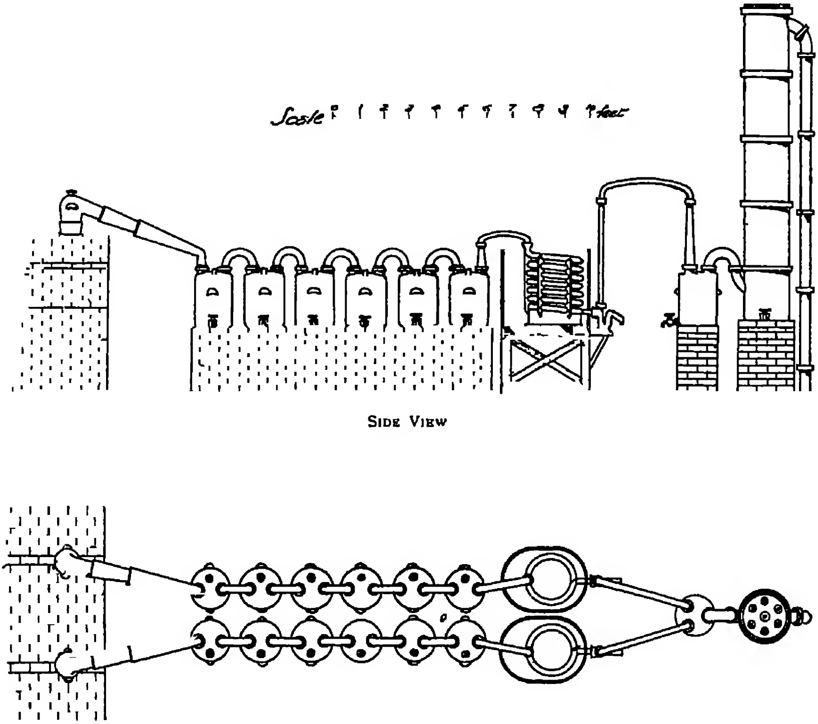
The worm that we have found to last best under the trying conditions which the condensing of nitric acid involve is that made by Drs. Plath and Piepmeyer. The outlet from the coil is connected with a series of Woulff's bottles, from which the finished acid is drawn.

The store for nitrate should be situated in close proximity to the nitric-acid stills, but it should be so separated as to prevent any risk of fire, as it is well-known that nitrate is very inflammable, so much so that in military explosives works great attention is given to the construction of the ventilating arrangements to such a house as to render it almost impossible for any spark to reach the store. In our own experience we have found it quite sufficient to keep the house separated from any building in which direct firing is used, and to so arrange it that a supplementary supply of nitrate from the store can be kept on a level with the top of the stills, so that it can be readily fed into them.

The acid store-tank for supplying the stills is best situated on a slightly higher level on this floor, so that the supply pipe leading from it to the stills has a sufficient fall to allow the acid to run readily into them. This tank should be of such dimensions and with such an arrangement for measuring the depth of acid, that the supply to the stills can be easily controlled. A very ordinary and simple method of measurement is by suspending strips of lead into the cistern, marks on the lead showing the

depths corresponding to certain quantities of acid contained in the tank.

In connection with the Valentiner process the arrangement for the pumps to maintain the vacuum requires special attention. These pumps should always be arranged in duplicate, so that should one break down no stoppage of the plant occurs, and in planning the arrangement of pipes this requires a good deal of attention. This system of pipes is frequently connected with a



SIDE VIEW

PLAN

FIG 28.—Small-scale Nitric Acid Plant.

battery of condensing pipes, of which Guttmann's is one of the best forms The pipes comprising the batteries are of special glazed earthenware, and are placed in tanks constructed of timber with connections for circulating the cooling water.

We cannot emphasize too strongly the necessity for using the very best rubber in the valves of pumps used in connection with this plant, as in actual experience we have had considerable trouble where inferior rubber has been used.

The pumps should be of ample capacity, and where electricity is the motive power they can be belt-driven or coupled direct to the motor.

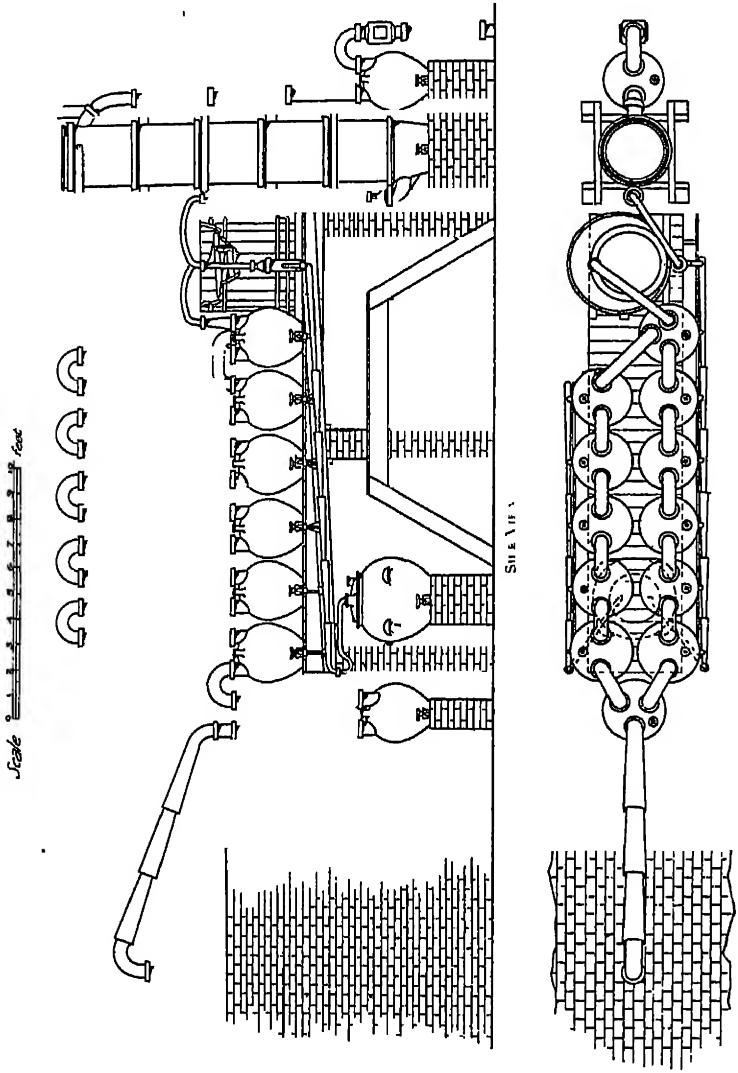


FIG 29.—Nitric Acid Plant

In planning the nitrate house, care should be taken that it shall occupy a very dry position, as nitrate very readily absorbs moisture. The nitrate is generally delivered in bags, and where use is not made of the bags, these are stored, and washed in

warm water, the washings being evaporated and the nitrate crystallized out. As the pressure of the nitrate against the walls of the house is very considerable, this must be taken into account when proportioning the thickness of the walls, the same remark applying to the walls of the nitre-cake store.

In connection with the mother-liquor well, an acid egg is probably the handiest means of raising the acid to supply tanks for further use.

Fig. 28 shows a small nitric acid plant by Messrs. Doulton & Co., of Lambeth. The illustration represents an ordinary plant for two small cylinder stills. The number of receivers is adjusted to the daily output of the still, the use of the condensing worms being optional. A wash-tower, suitably packed with coke, or with stoneware balls or rings, may be connected to several batteries, to effect the final condensation of the gases

The apparatus shown in Fig. 29 represents a plant by Messrs. Doulton & Co., for an output of about 1 ton of nitric acid per day. The plant includes several improvements in detail, the capacity of the receivers being supplemented by long stand-pipes to a common collecting jar, in which the acid of all the receivers and the worm is mixed, and the receivers being kept empty, their full condensing power is utilised. An end tower, packed with coke or hollow stoneware pieces, is provided to wash the exit gases.

CHAPTER VIII.

NOTES ON HIGH EXPLOSIVES PLANT.

In touching on high explosives, reference is made mainly to those in which nitro-glycerine compounds play the most important part.

The chief features of a high explosives factory may be divided into three groupings: (1) the group comprising the acid manufacture; sulphuric acid, if this is made on the spot instead of being purchased, and nitric acid, this latter dealing also with the mixed acids and the concentration of the weak sulphuric acid; (2) preparing the gun-cotton, and nitrating, washing, pulping and drying, bringing the product to the stage of gun-cotton; and (3), the manufacture of nitro-glycerine and incorporating with the gun-cotton to form cordite.

In the manufacture of vitriol for use in the production of high explosives, an acid practically free from arsenic is required, and the acid is usually made from sulphur, requiring a different form of burner to that described for the manufacture of sulphuric acid from pyrites, but the chambers are practically the same, and therefore do not require further description here.

We have already described the plant for the manufacture of nitric acid for general use, but with regard to its manufacture relative to explosives, the dealing with the waste acids returned from the nitro-glycerine department, and also the mixing of the acids for the nitrating department, necessitate considerable additions to the acid plant Concentration plant is also necessary for bringing up the weak sulphuric acid to the requisite strength for re-use. The plant most recently adopted for concentration, especially in connection with explosives manufacture, is that of Kessler, which is now well known

The mixing of the acids is all performed by compressed air, this being also used for conveying the acids to the nitrating department and also to the nitro-glycerine department.

Gun-Cotton.—Dealing with the gun-cotton department, the first process is that of opening the cotton waste and picking it, after which it is passed through a "devil" or breaking machine. On leaving the breaker, it is further hand-picked, to free it from all impurities and dirt, and then placed in a drying stove, which is usually steam-heated to the required temperature. A weighing machine is provided here, for weighing the different charges given out to the workmen for nitrating, and the cotton after being dried in the stoves is placed in air-tight tins preparatory to use, in order to prevent the absorption of moisture from the atmosphere.

The nitrating or "dipping" house usually adjoins the cotton-drying department, the cotton being passed through apertures in the wall dividing the two sections. In the dipping house, each workman has an acid tank for dipping the dried cotton, immediately it is received from the drying house. A hood extends over these tanks and is provided with a fan-shaft, to take away the fumes which emanate from the tanks during the dipping process. Immediately on dipping the cotton, the workman squeezes it as free as possible from acid by specially made hand squeezers, and places the nitrated cotton in earthenware vessels provided with lids. On having worked a charge of these in the pots ranged at the back of the man, he then takes them to the cooling troughs which extend lengthwise of the house, and which are kept filled to a depth almost equal to the depth of the earthenware pot with cold water.

The roof over the dipping house should be provided with a louvre. Great care must be taken that the louvres are sufficiently deep to prevent rain being driven in, as in the event of any of the pots being uncovered and water dropping on the contents, these would immediately take fire.

The nitrated cotton, after remaining for the correct length of time in the earthenware jars in the cooling pits, is conveyed to a centrifugal, where the contents are quickly emptied into the basket of the machine and covered with a special lid. The bulk of the nitric acid still remaining in the cotton is thus expelled, the acid running away to an egg, from which it can be returned to the nitric acid department, and the cotton is at once plunged into tanks of water, these tanks being constructed

in like manner to other acid tanks, that is, with timber framework, and are lead-lined.

This preliminary washing of the nitrated cotton has to be done quickly, otherwise it would take fire. It is not an infrequent occurrence for a centrifugal of the nitrated cotton to ignite, and even when this does not happen, considerable fumes are given off from the centrifugal during the operation of "whizzing," and a cowl, with fan attached for carrying away the fumes, is also necessary here. After washing in the lead-lined vats, the cotton is again placed in centrifugals, and on leaving these it is carried to the boiling department.

The boiling is performed in large wooden vats, having a false bottom, and fitted with perforated steam pipes underneath the false bottom. As the vats are usually made from nine to ten feet deep, the working floor is generally raised in the form of an open woodwork grid, the level of which is placed at from 3 feet 6 inches to 4 feet from the top of the vats. Here, again, the nature of the process requires a well-ventilated house, and the louvre type of roof is admirably adapted for this purpose. The vats most commonly in use are made of Scotch fir, and generally taper in the same way as brewers' vats, so that the diameter at the top is about a foot less than at the bottom. The false bottom already mentioned is placed about 12 inches from the bottom of the vat, and is usually pierced with circular holes, and is so arranged that it can be removed to give access to the perforated steam pipe placed underneath it The vats are generally made of 2-inch timber, and are circular in shape, bound round with iron bands at suitable distances in the height. In some cases, oak vats are preferred, but the cost of these is greater, and as their life is not much longer than those of good Scotch fir, they are placed at a disadvantage in comparison with the latter, in this respect.

The next process after boiling the nitrated cotton is that of pulping. After running the water away from the vats, the cotton is passed into the beater house, where a thorough pulping takes place.

From the beaters the pulp runs away by means of troughs to the centrifugals, where it is once more dried, and is ready for taking to the wet stores, whence it is given out for finishing off in the drying stoves

This brief description completes the gun-cotton process. In the manufacture of cordite, as previously mentioned, nitro-glycerine and gun-cotton form the chief ingredients. As regards the actual manufacture of the nitro-glycerine, this takes place in a house which is commonly known in works of this kind as the nitro-glycerine hill. In common with most other buildings in an explosives factory, this house is constructed of timber, and, as far as is consistent with strength, is as light as possible, especially as regards the roof and sides. The apparatus used varies in design, but the chief feature is the mixing vessel, which is usually made of lead, with observation glasses on the cover, while inside it is fitted with cooling coils through which water circulates, to keep the contents at a given temperature. The mixing of the acids and glycerine is done by means of compressed air. The refrigerating plant supplying the cold water, and also the air compressors, are contained in a building at a stipulated distance from the nitro-glycerine hill, according to the regulations appertaining to explosives factories.

Centrifugals for Gun-cotton.

The machines shown in Figs. 30 and 31 have been specially designed by Messrs. Pott, Cassels & Williamson, of Motherwell,

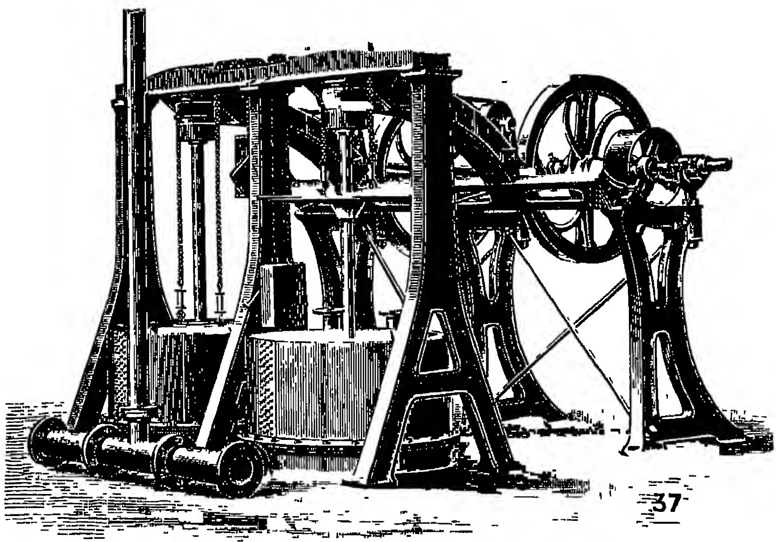


Fig. 30.—Machine for Drying Gun-cotton.

Scotland, for drying gun-cotton after being treated with nitric acid. The baskets are made of wrought iron with specially rounded covers so as to facilitate the removal of the gun-cotton. The outer cases are made of cast iron so as to withstand the action of the acid, and are strengthened outside with a steel case. The machines are fitted with hinged or lifting covers, and with vent pipes connected with a steam jet or fan to carry away the acid fumes.

Fig. 32 is a special machine designed for nitrating the gun-cotton and drying it in one operation, thus doing away with handling the gun-cotton from the nitrating tank to the centrifugal The basket is made solid, that is, not perforated. The cotton is put into the basket, which is then filled up to the

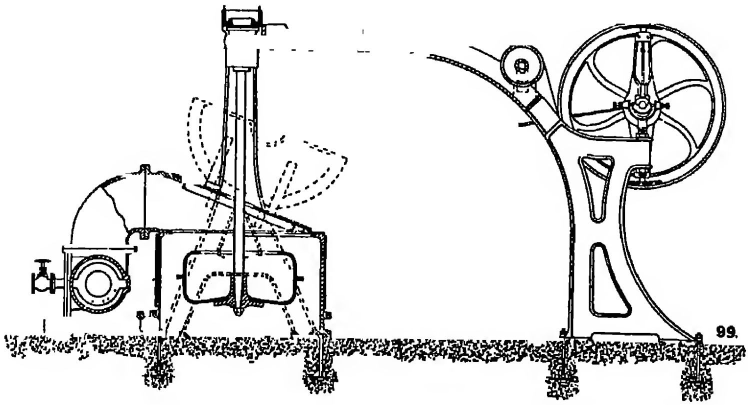


Fig. 31 —Machine for Drying Gun-cotton.

flanged lip with nitric acid. After being well soaked, the machine is started and the surplus acid is discharged through the opening or slit between the flanged lip and the cover of the basket.

In the apparatus shown in Fig. 33, by Doulton & Co , Ltd., the mixed waste acids from the manufacture of gun-cotton, etc., are separated, and the nitric acid condensed The mixed acids are run into the first column, which is packed with quartz or other suitable filling, and separation of the sulphuric and nitric acids is effected by the injection of steam. The dilute sulphuric acid runs off at the bottom into a cooler, and is subsequently re-concentrated for further use, while the nitric acid vapour is condensed in the receiver battery shown The weak acid can be circulated in the towers until strong enough to be of use.

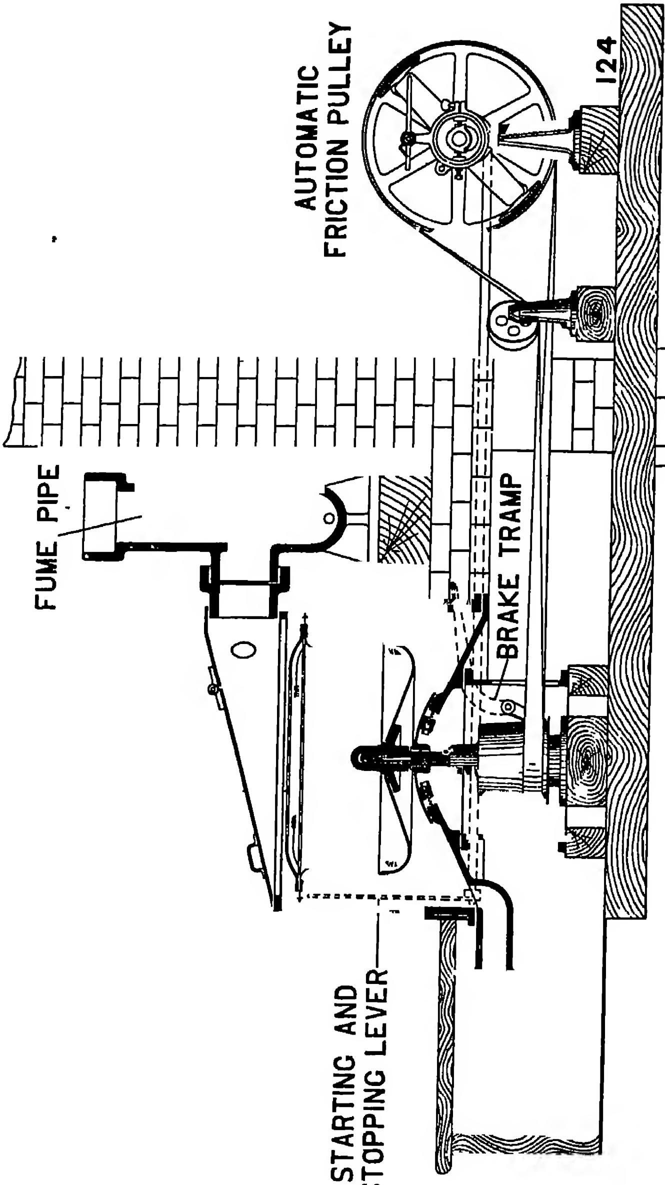


Fig 32.—Machine for Nitrating Gun-cotton and Drying in One Operation, by Pott, Cassels & Williamson.

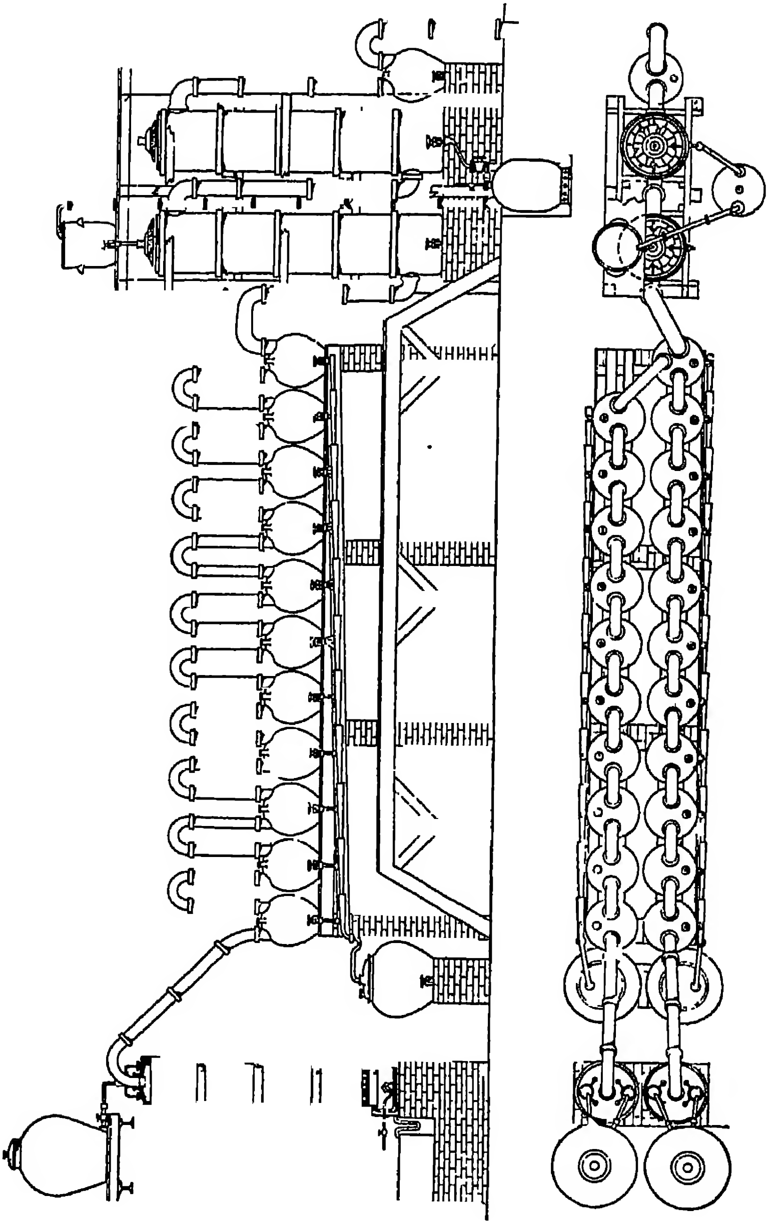


Fig. 33.—Denitration Apparatus, by Doulton & Co., Ltd.

Air Compressors.

Compressed air is daily finding a more extended use in chemical works, and in all manufacturing operations of a

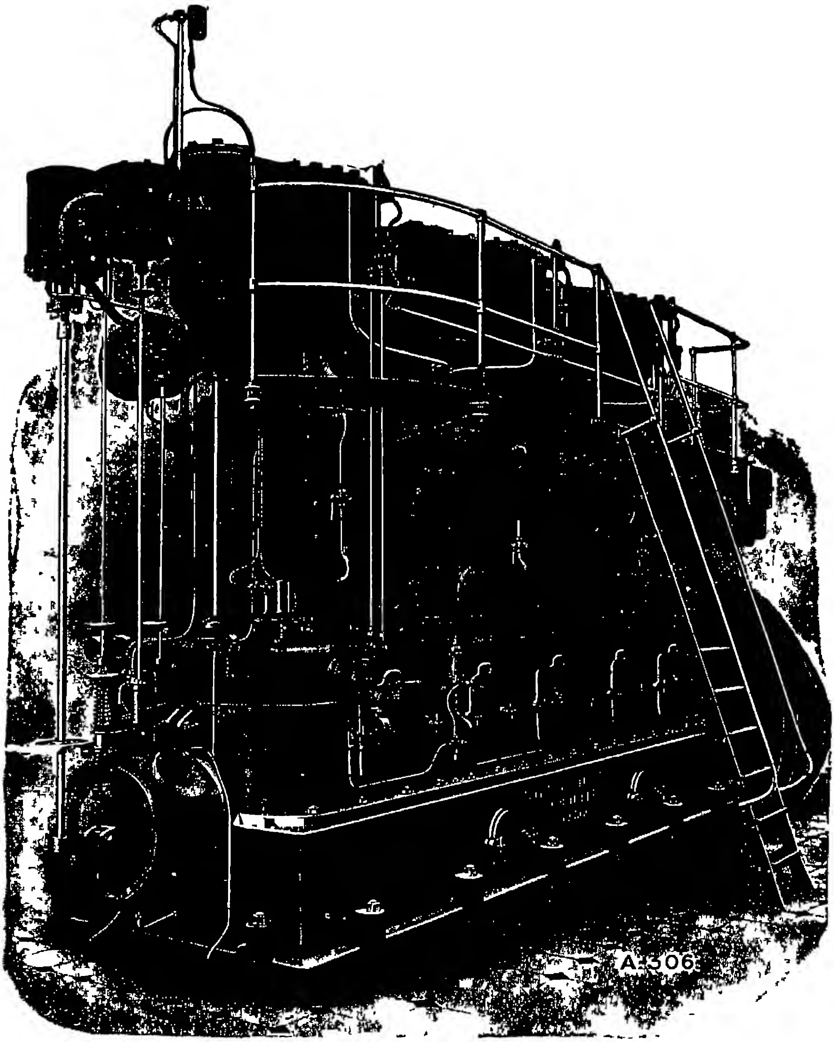


Fig 84.—The "Sentinel" Compound Intercooling Air Compressor.

chemical nature. Chemical and explosives works in particular often extend over considerable areas, about which are placed

small engines and pumps. In explosives works it is not advisable to use electric motors, and in many chemical works the acid vapours would render the upkeep of the conductors and the electric plant generally an expensive and troublesome matter. Over such large areas the condensation of steam and the upkeep of the water-logged steam pipes is very wasteful, and in such works compressed air is capable of effecting considerable

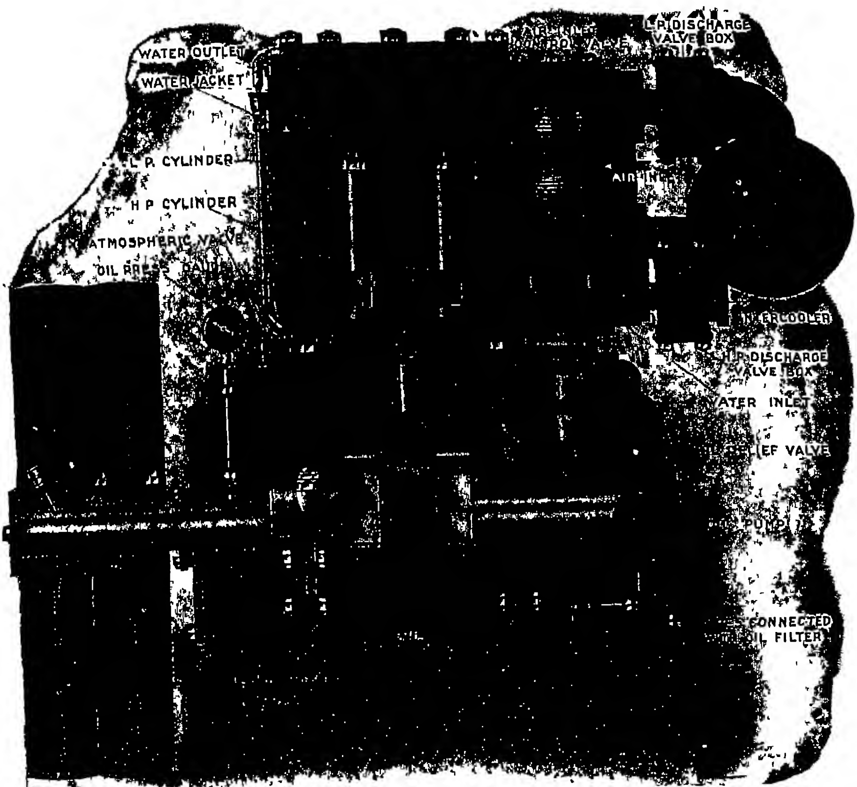


FIG. 35.—"Sentinel" Air Compressor (Sectional View), by Alley & MacLellan, Ltd.

economies. It may be and is used very advantageously for driving isolated engines, pumps, and hoists; for blowing, elevating, and agitating liquors, and for various special purposes. Acids can be moved about without dilution, and without coming into contact with anything but the piping, while a compressed air supply is of course necessary in oxidizing processes.

Figs 34 and 35 show a "Sentinel" compound intercool-

ing steam-driven compressor, by Messrs. Alley & MacLellan, Limited, of Glasgow, capable of delivering 5000 cubic feet of free air per minute; 100 lb. air pressure, 160 lb. steam pressure.

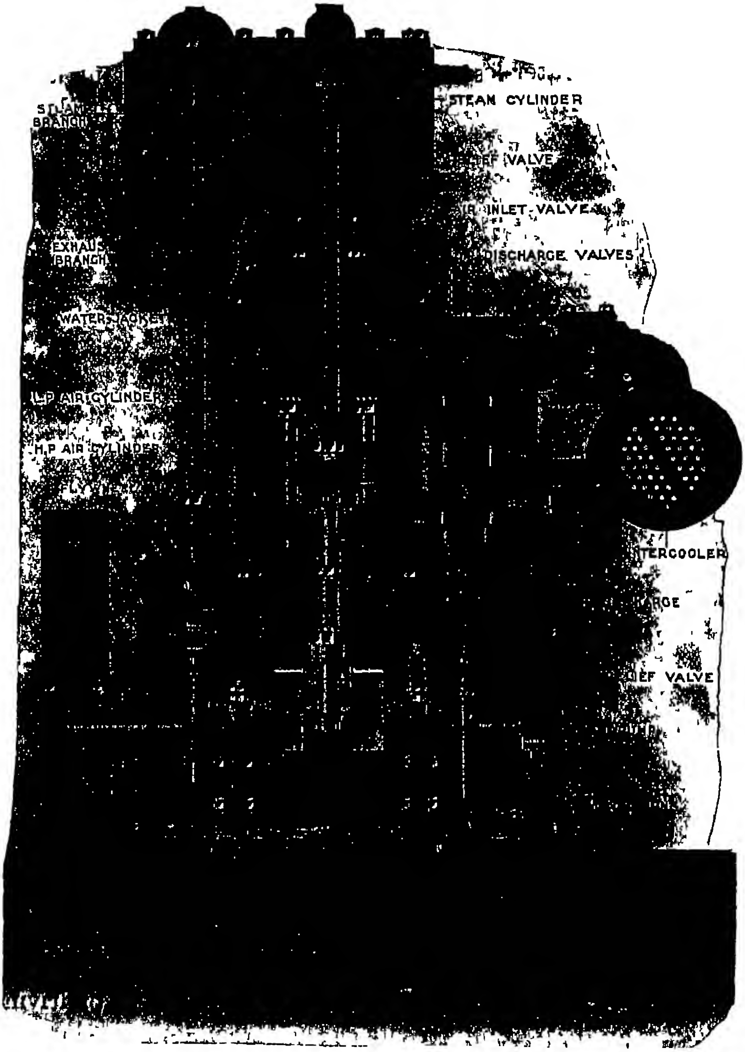


FIG. 36.—"Sentinel" Steam driven Compound Intercooling Air Compressor single-line machine, by Alley & MacLellan, Ltd.

This is a very powerful installation; but smaller units of plant are equally efficient.

Many air compressors are very wasteful of power, but this is

not the case with the type of machine here illustrated. The makers have brought to bear their great experience in the construction of a machine which gives a very high economy. As an indication of what it is possible to achieve in this direction, a horizontal air compressor of 400 feet capacity has been replaced with a "Sentinel" of 1200 feet capacity, with a guaran-

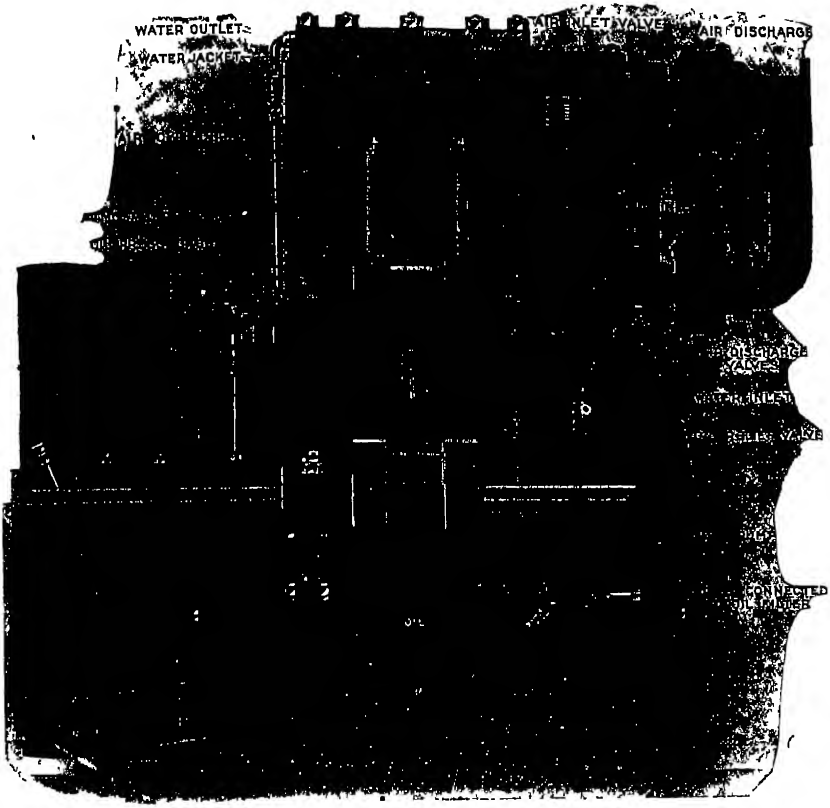


FIG. 37.—"Sentinel" Single-Stage Air Compressor, by Alley & MacLellan, Ltd.

tee that no more steam should be used for the larger output. This machine cost the buyers £1200, and saved its entire cost in fifteen months.

Fig. 36 shows the "Sentinel" steam-driven compound intercooling air compressor—single-line machine with simple steam cylinder. These machines are made with one, two, and three lines of parts, with simple and compound steam cylinders, all

having air compound cylinders fitted with intercoolers. The illustration shows the cylinders and their gear in section.

Fig 37 shows a "Sentinel" single-stage compressor, for working pressures to 60 lb per square inch. This machine is arranged to discharge air at the working pressure from both above and below the trunk piston head No intercooler is required,

The "Sentinel Junior" single-stage compressor, shown in

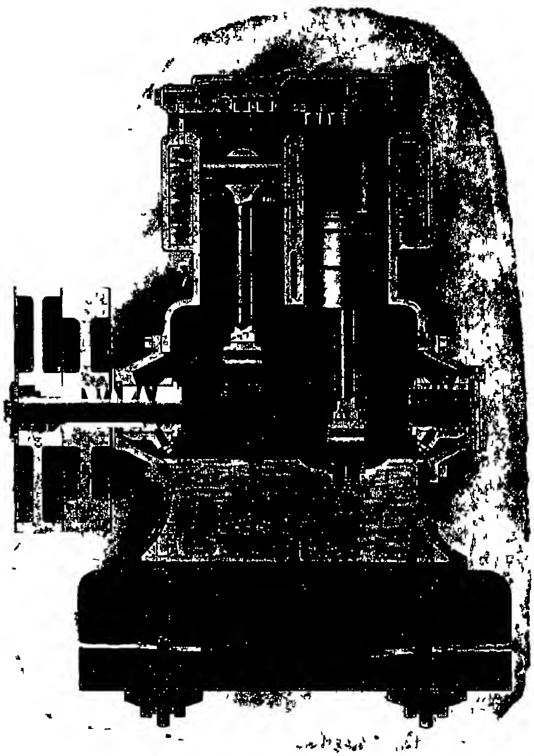


FIG. 38.—"Sentinel Junior" Single-Stage Air Compressor, by Alley & MacLellan, Ltd.

Fig. 38, will be found convenient where only a small amount of compressed air is required, or where compressed air is not constantly used, or for low-pressure work Under such conditions the saving in power by using compound intercooling would not justify the extra expenditure, and in the case of low-power this type of compressor is quite as economical.

CHAPTER IX

SULPHATE OF AMMONIA PLANT.

AGAIN the vitriol chambers figure prominently in the manufacture of sulphate The question of erecting their own sulphuric acid plant is one that has received much attention during recent years on the part of large makers of this product, such as gas works and corporations, as also in connection with recovery plant for dealing with the by-products from coke ovens.

In the case of gas works, it has been the custom to deal with the gas liquor on the spot, treating the gas liquors for the recovery of ammonia as sulphate, and disposing of the tar to the tar-distiller for subsequent treatment, as the separation of the ammoniacal liquor from the tar is readily effected at the gas works.

In the smaller gas works dealing with the liquor produced from the carbonization of moderate quantities of coal, the method of operation is generally as follows

The liquor is subjected to distillation by means of steam in a column still. The plant consists of the following parts. Starting from the store tank, which is often placed underground, and of concrete or brick cement-lined construction, the liquor is raised to an over-head supply tank of cast or wrought iron, placed sufficiently high to be well above the stills. Between the supply tank and the still it is customary to place a smaller regulating cistern, which can be easily adjusted to the capacity of the still.

The Still.—Many forms of still are in use, some of which are better suited for dealing with a weak liquor than others, but the type most generally employed in gas works, where the strength of the liquor is usually equal to 8 ounce, are more or less of the Coffee pattern, which consists of a cylindrical column of cast iron, built up of segments forming trays. The liquor, entering at the top of the still, finds its way from tray to tray,

until finally it flows out from the bottom segment, free from ammonia.

In some patterns the still combines three portions: an upper series of trays; a central portion; and a lower series of trays. In the central portion, which is usually equal to the combined depth of the upper trays, lime in the form of a milk is admitted, and in the lowest segment of the lower series steam is admitted, the steam finding its way up the still through a series of openings in the trays, these openings being covered with a cap forming a lute. The steam bubbles through the liquor, and ultimately finds its exit from a pipe in the top part of the still, known as the still-head.

The pipes conveying the liquor from tray to tray stand up above the liquor in the one tray, the lower portion of the pipe projecting through the tray into the tray immediately underneath it, and dipping into the liquor in that tray to form a seal. In this way none of the ammonia gas liberated by the steam can escape through these dip-pipes, but is forced to bubble its way through the liquor through the serrations in the cap placed over the gas inlet of each tray.

The free ammonia is set at liberty by the steam in the upper trays, and the liming chamber is introduced to supply the lower trays with milk of lime for the purpose of liberating the remainder of the ammonia (which is present in the liquor in the fixed condition) as it flows through the series of lower trays.

In many cases the liquor as it leaves the still with a large amount of lime in suspension is run away into settling tanks, but sometimes, before doing so, advantage is taken of running it through a series of pipes, or a coil placed in a tank in which the water for the milk of lime pans can be heated before being fed into the liming chamber. Before the crude liquor enters the still, it is heated by means of the waste heat coming away from another portion of the plant known as the saturator, which will be described later. The gases from the saturator are passed through an apparatus known as a heater, of which, again, there are many forms. In some cases the heater takes a similar form to the still, the difference being that the gases from the saturator enter the lower chamber, from which a series of pipes pass through a centre chamber and terminate in an upper shallow chamber. The gases pass up the pipes and away from an exit

pipe from the upper part of the chamber, and the liquor from the regulating tank flows into the middle chamber surrounding the pipes through which the hot gases pass, thus heating the liquor before it enters the still.

The Saturator.—The saturator is a lead-lined vessel divided into two portions, in one of which the gases from the still enter through a continuation pipe from the still-head to the bottom of the saturator, and ending in a branch pipe perforated with a number of holes. The other portion of the saturator is open at the top (see illustrations, Figs. 39, 40, 41 and 42). The covered part of the saturator has another pipe, already referred to as leading the hot gases generated in the absorption of the ammonia, to the heater. The saturator mentioned is the cheapest form, where hand-fishing of the sulphate is adopted, but even where hand-fishing is still in use, if the initial expense is not a serious consideration, we strongly recommend the solid lead saturator which is to be found in more modern works, as the life of this is far greater, and there is very little risk of leakage, which is more likely to occur with a timber lead-lined vessel. We have seen many of these solid lead saturators in use, and the accompanying illustrations show one of these, as made by Messrs. Joseph Taylor and Co., of Bolton, who have made a speciality of this class of work.

The lead used in the building of the plate-lead saturators illustrated is manufactured by Messrs Holman Michell & Co., of St. Helens, Lancs., who are well-known by reason of their long and successful specializing in the production of "chemical lead" for this purpose and also for vitriol chamber construction, etc. Messrs. Holman Michell & Co.'s lead-rolling mill is one of the largest and best equipped in existence, and in it the lead plates for the construction of the saturators (which are made up by Messrs. Joseph Taylor & Co.) are made. The ingot lead used is from the finest ores, desilverized by the Pattinsonian process, and after melting down and again refining the metal is run off into a block 9 feet by 8 feet by about 6 inches deep, and weighing about 10 tons. This block, when somewhat cooled, is lifted and run under the rollers of the mill until reduced to the desired thickness, and can then be cut into the required sizes. From a block of this size plates 8 feet or 9 feet wide can be rolled, or thinner sheets of 40 feet in length can be

obtained. The saturators must be made up with a minimum of seams, and this burning is done by a special process, giving seams which are clean, solid, and dense throughout.

In the working up of ammoniacal liquor, the quality of the leadwork, and particularly the saturator, is most important. In dealing with boiling sulphuric acid (and sulphate of ammonia cannot be successfully produced without a good boil in the saturator) only lead of the very best quality is admissible, as,

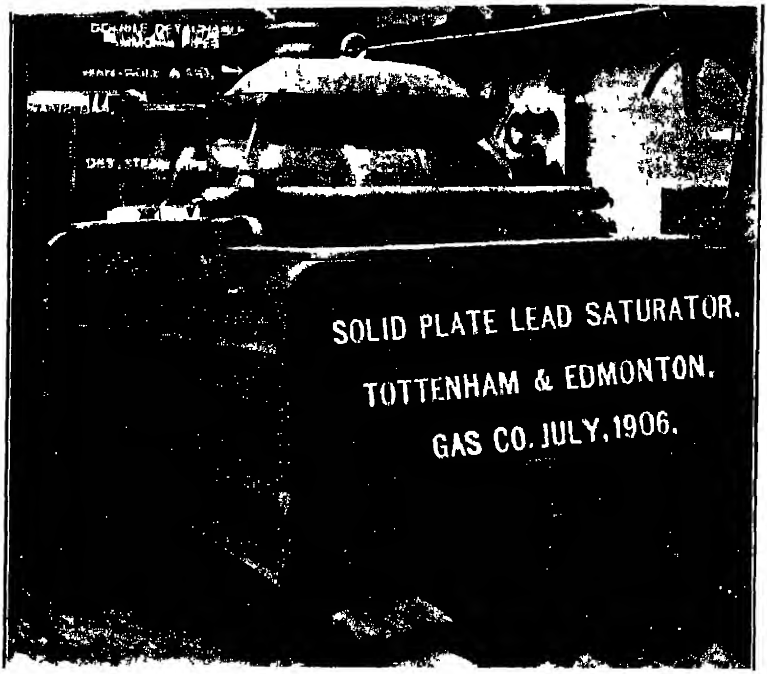


FIG. 39.—Sulphate of Ammonia Saturator, by Joseph Taylor & Co

apart from the loss sustained through leakages, there is the subsequent uplifting of floors and foundations, and cracking of buildings due to the great expansive nature of the leaking liquor, when this has once permeated the floor and surroundings.

Saturators in coke-oven and blast-furnace plants are on the boil year in and year out, boiling continually, so that the question of constructing a saturator which will keep its shape, apart from its lightness and effectiveness, is a most important one.

Fig. 40 shows a saturator, sulphate drainer, and sulphate store at the Leigh Gas Works, Lancs. In Fig. 39 a solid plate lead saturator such as described above is illustrated, being fitted with double detachable ammonia pipes, man-hole and lid, waste gas pipe, detachable steam pipe, and detachable acid pipe. Fig. 42 shows an overhead view of a $\frac{7}{8}$ inch plate-lead saturator worked from one plate, with one seam only, while Fig. 41 shows a saturator fitted with well for Wilton's discharger.

Milk of Lime.—There are various forms of apparatus for mixing up the milk of lime, such as the circular agitated milk

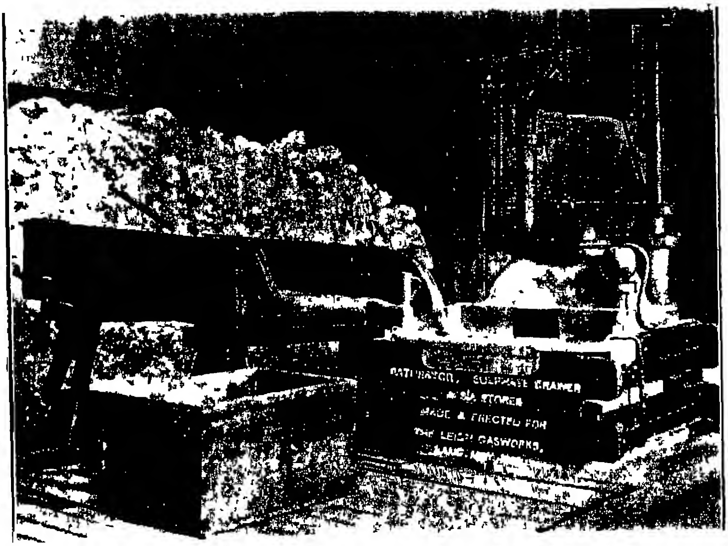


FIG 40.—Sulphate Saturator, Drainer, and Store.

of lime pans used in alkali works, or the very neat liming apparatus in which a steam jet is used, as made by Messrs. Meldrum Bros. of Manchester.

Miscellaneous.—Apart from this plant, there is the acid supply tank, water supply, and mother-liquor well, which receives its supply from the liquor draining away from the sulphate after it has been fished from the saturator by means of a perforated scoop and deposited on the draining table, which is generally situated to the left hand of the sulphate maker.

Adjoining the saturator is the sulphate store, and after

the preliminary draining of the sulphate on the draining table adjoining the saturator, this is generally thrown from the draining table on to the grid of the sulphate store, which is constructed with a gradual inclination towards a gutter draining

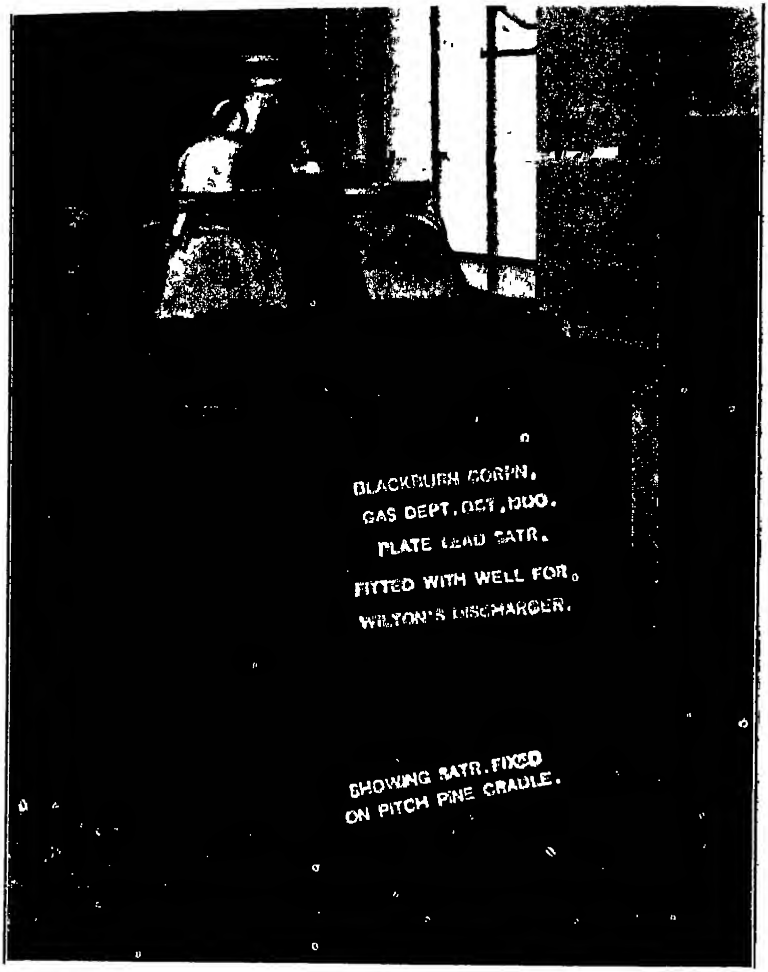


FIG. 41.—Sulphate Saturator with Well for Wilton's Discharger.

into the mother-liquor well The liquor from the mother-liquor well is used again in the saturator, being raised by an injector placed in a suitable position to be operated by a man while standing over the saturator

Hand-fishing as described above only applies to plants dealing with comparatively small quantities of liquor. In larger

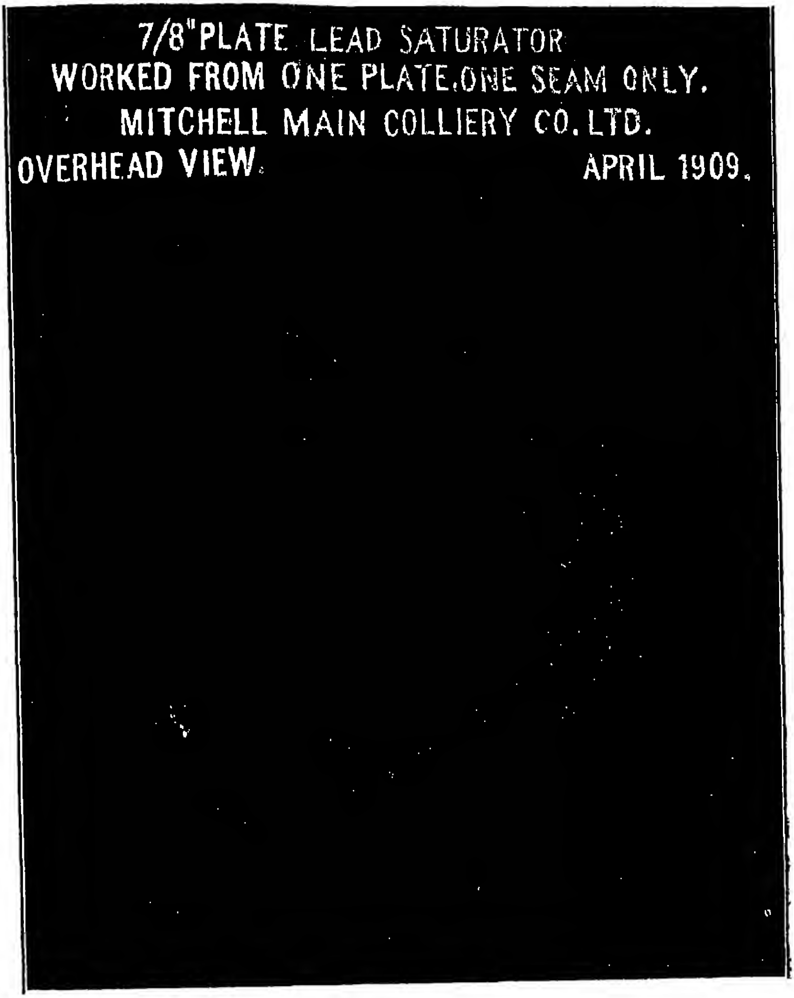


Fig. 12.—Overhead View of Solid Plate-lead Saturator.

plants it is customary to dispense with hand fishing, the sulphate being lifted mechanically from the saturator and deposited in centrifugals with a bottom discharge.

CHAPTER X.

NOTES ON ARTIFICIAL MANURE PLANT

In an artificial manure works, as in an alkali works, one of the chief features of the plant is the acid chambers In a manure works, however, it is usual to have a much deeper upstand, as the acid is not drawn off in the same quantity all the year round as in an alkali works It is a common practice to allow the acid to accumulate until a considerable depth is reached in the chambers, and in this way to form a store for the busiest part of the season, which is generally the autumn, to make for the spring.

In the case of vitriol chambers for manure works, it is not uncommon for the upstands to be made of as great a depth as 3 feet. Consequently, the construction as regards the lower portions of the structure, platforms, and columns must be proportionately stronger, in view of the additional weight of acid.

Burners —As in many alkali works, the burners may be placed under the chambers, or, as we have seen in some works, they may be placed alongside the chambers, the space under the chambers being utilized for accommodating the storage bins for the manure.

Manure Dens.—In close connection with the chambers are the manure dens. Several designs for these have come under our notice In some cases the dens are built of comparatively small dimensions, and the mixer is placed in a central position above these dens, with troughs from the outlet which can be moved to a central aperture, so as to feed into any one of say a group of four dens, but we are rather in favour of the adoption of a larger den, with the mixer placed in the central position, and built in a group Plate IX shows a good arrangement of dens, mixers, etc.

Mixers —There are several forms of mixer on the market, all of which have certain merits, which are perhaps embodied in the

one made by Messrs. Pratchitt Bros. of Carlisle, and again that of Messrs. Newell of Newark. The mixer by Pratchitt Bros. is circular in shape, with a drop bottom, while the one by Newells is a horizontal mixer and has its discharge at one end.

It will at once be apparent that in the first method referred to, of discharging from one mixer into several bins, the mixer would require to be placed at a sufficient height to give a necessary slope to the inclined shutes into the bins for the mixture to fall by gravity, but where the mixer is placed over the centre of a den no shute is required, as the manure, as it falls into the den, will find its own level. In a den say 20 feet by 20 feet square, it is necessary to draw off the gases evolved during the heating of the manure after being deposited in the den. These gases must be allowed to escape freely to a central shaft connected with a condensing tower, the exit gases from this condensing tower again in turn being connected with the main flue to the chimney

The opening to the dens is formed by a heavy movable door, but in many cases the den is closed by making it up with battens, which rest in a groove left between the girders which span the opening, and a similar groove at the ground level. These battens are slid along, and a cross-board is dropped in supports provided for that purpose at either side of the opening, thus forming a firm resistance to the manure within the den. In this latter case the boards should be roughly luted up with a daub of "black stuff".

The breakers or disintegrators are generally placed close to the dens, so that as the manure is brought out of one den it can be conveyed readily to a disintegrator, which breaks it up and delivers it on to a rough circular sieve, which passes on the fine manure to be dealt with by further mixture and sieving, while the lumps or nuts that have not passed through the sieve are returned by a shute, to be again passed through the disintegrator

We have not so far spoken of the storage of the raw materials, such as offal, shoddy, bones, phosphates, etc , used in the mixing. The stores for these materials should be so arranged as to admit of ready unloading, and should be next to the grinding department, where the ingredients are dealt with previ-

ous to being elevated to the store bins over the mixers and manure dens.

In connection with the packing department we must take into account the space required for storing sacks, bagging, etc., and in the actual work of packing, the sack-holding arrangement of Mr Richard Simon of Nottingham is a very useful contrivance as a labour-saving device

CHAPTER XI.

NOTES ON GENERAL PLANT.

Acid Elevators.

The old-fashioned acid egg is still employed in many vitriol works for the purpose of raising acids from the ground level to the tops of the various towers of the plant, but of recent years the employment of automatic acid elevators has become very general, and in designing an up-to-date plant their adoption is almost a matter of course.

Kestner's elevator for sulphuric acid is shown in Fig. 43. It consists of a cast-iron body, B (lined with lead if weak acids are to be dealt with); a lead-lined vertical stand-pipe, T; air distributing box, D; lead floats, X Y; lead-coated steel rod, *c*; delivery pipe, T_1; feed pipe, T_2; regulus metal check valve, M; and compressed air pipe, T_3. It is necessary that the apparatus should be fixed vertically, and the acid in the pipe must not rise higher that the level G——F In working, the acid enters the body of the elevator by the feed pipe, fills up the vessel, and raises the float, which acts upon a valve in the air-distributing box. When under air pressure, the acid rises through the delivery pipe, and when the vessel is emptied the air is cut off and escapes from the vessel, which again fills. The float again rises, compressed air is admitted, and the operation is repeated.

This elevator is largely used, not only in vitriol works, but in connection with explosives plants, and all factories where acid is required to be raised In slightly modified forms it can be used for hydrochloric acid and nitric acid, or for liquids containing chlorine.

Fig. 44 shows the Kestner elevator for hydrochloric acid. The parts are as follows. B, sheet-iron body, lined with ebonite; T, ebonite-lined stand-pipe; D, distribution box; X Y, ebonite float, C, steel rod coated with ebonite; T_1, discharge pipe; T_2,

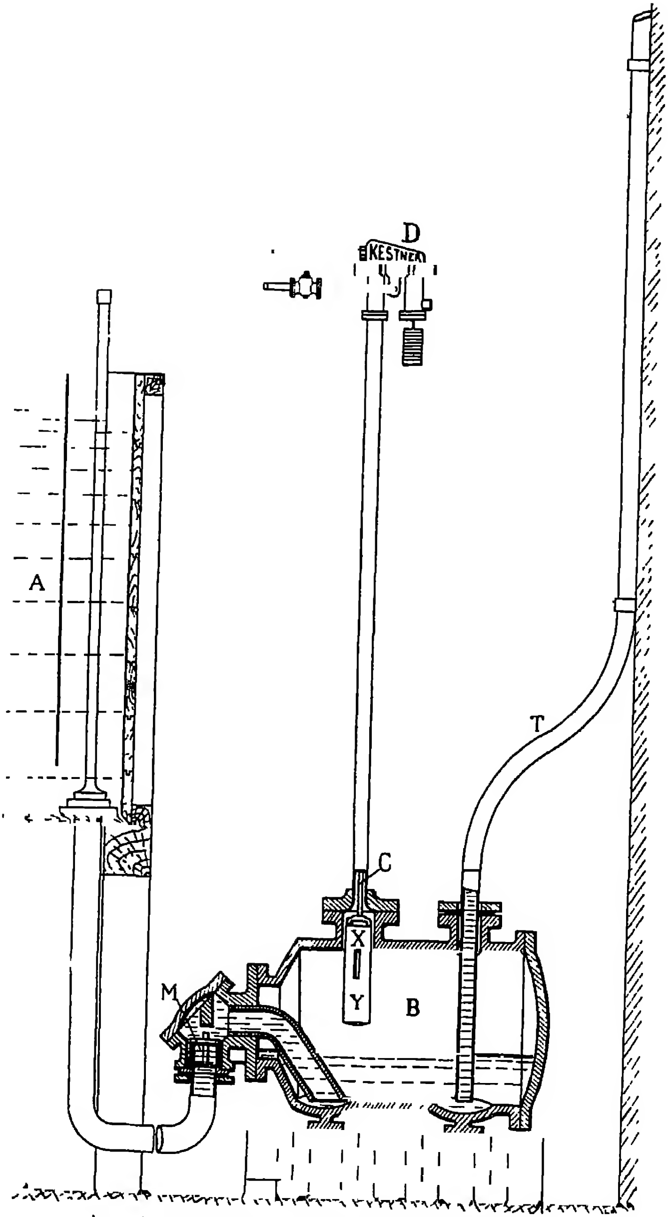


Fig. 43 —Kestner's Elevator for Sulphuric Acid

feed pipe; M, ball check valve. The line G——F shows the highest level allowable for acid in the feed cistern. This elevator is simple and steady in working, and it has been very generally adopted.

Fig. 45 shows a cheaper form of Kestner's elevator for hydrochloric acid, acetic acid, and acid liquors generally. It is worked with less head of feed. Made of earthenware, it is tested to a pressure of 75 lb. before being sent out by the makers.

The parts of the apparatus are as follows: B, stoneware cylindrical body; T, stand-pipe; D, air distribution box; X, ebonite float; M, india-rubber ball valve; T_1, delivery pipe; T_2, feed pipe; G——H, highest level of acid in feed cistern.

Fig. 46 shows an earthenware elevator, also made by Messrs. Kestner, for raising nitric acid. This elevator has been adopted by the principal explosive factories, and in many of the Government powder works, both at home and abroad. It is a most reliable elevator, and all parts in contact with the acid are of earthenware.

The elevator is built up as follows: B, stoneware cylindrical body, T, stoneware

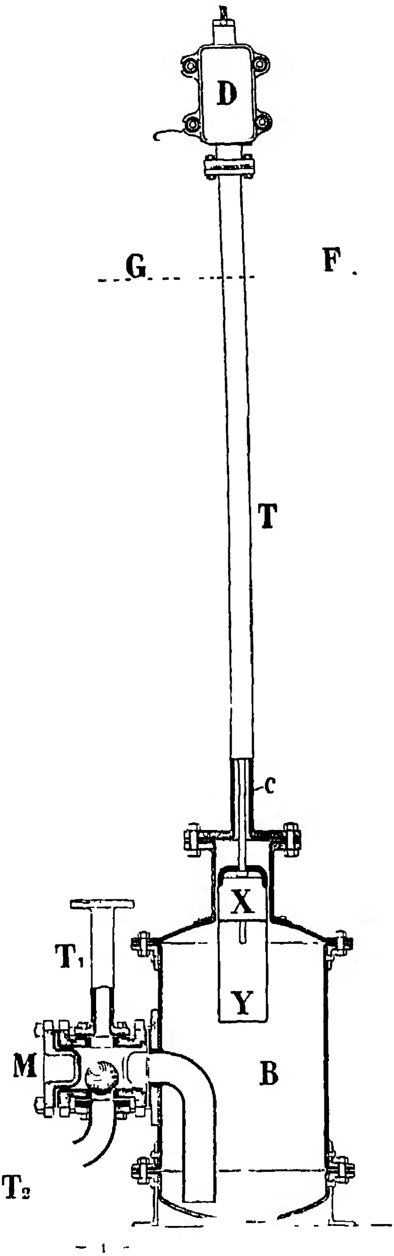


Fig. 44.—Kestner's Elevator for Hydrochloric Acid.

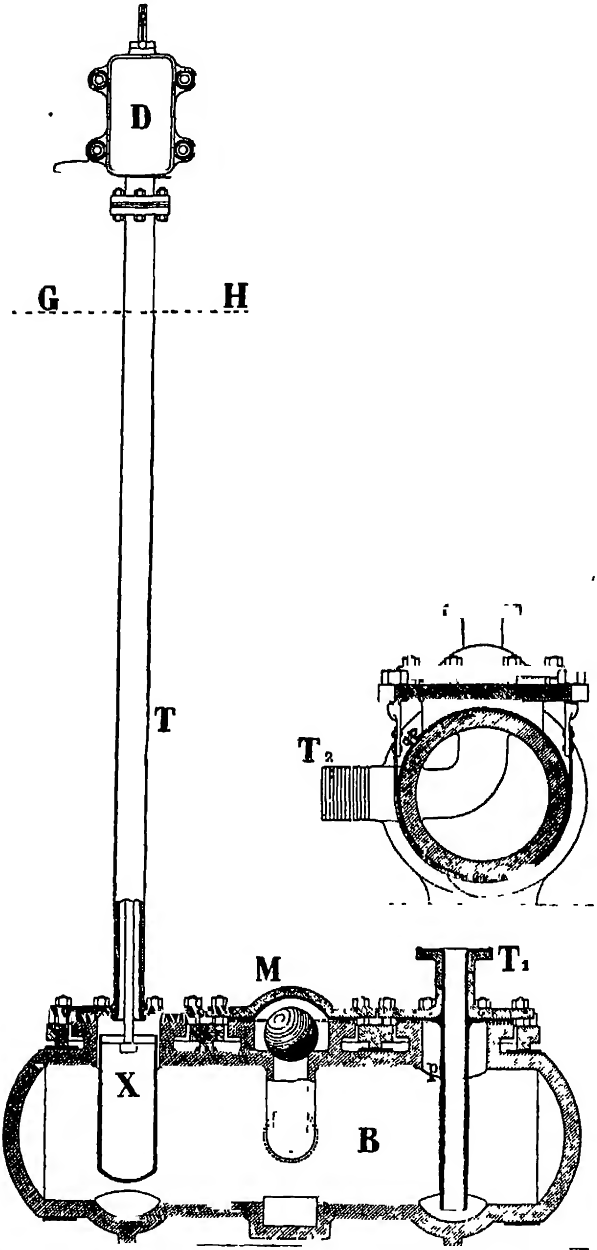


Fig. 45.—Kestner's Earthenware Elevator for Hydrochloric Acid, etc

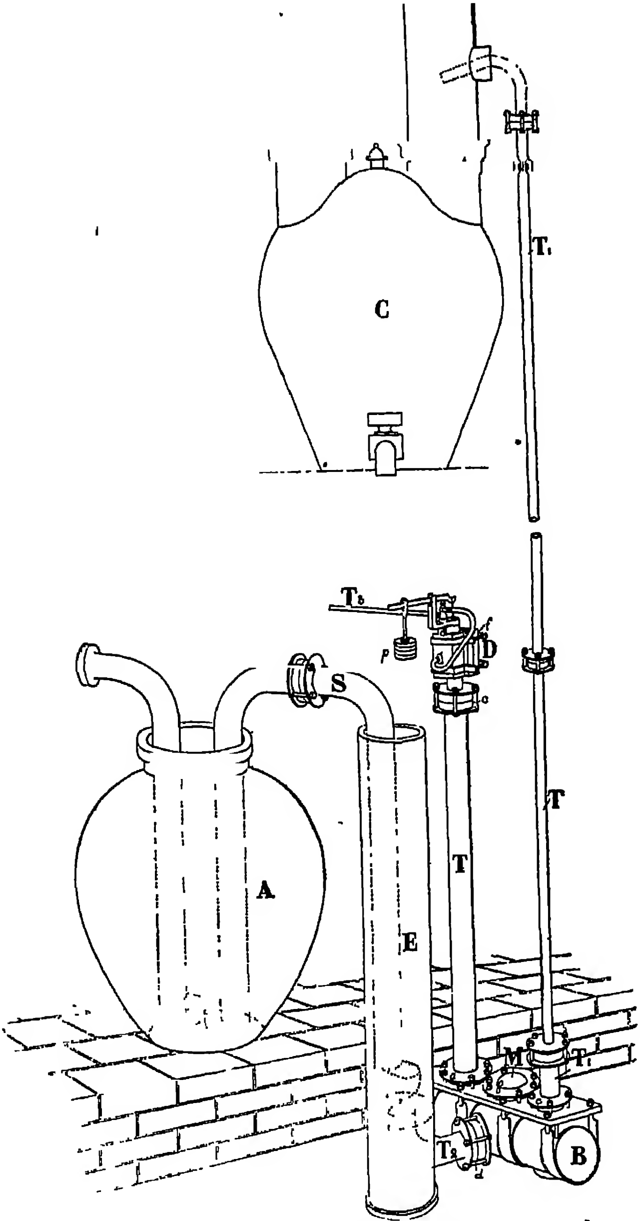


Fig 46.—Kestner's Earthenware Elevator for Nitric Acid.

stand-pipe; D, stoneware distribution box; M, stoneware check valve, T_2, acid feed pipe, T_1, acid discharge pipe; E, stoneware feed cistern; S, syphon; A, feed reservoir; T_3, compressed air supply pipe; C, stoneware delivery cistern.

It often happens that acids have to be elevated to a point situated at a height superior to the one corresponding to the pressure of compressed air used; it is then either necessary to change the compressor, or to raise the acid in two stages; that is, with a stand at half-height. M. Kestner applies emulsion to lighten the delivery column, and this by simply piercing a small hole in the part of the delivering pipe which is contained in the elevator. Part of the compressed air escapes by this hole directly through the delivering pipe, in which it forms the Pohle's bulb chain for easing the delivery.

This arrangement admits of the height of Gay-Lussac towers in a vitriol works being increased without raising the pressure of compressed air or working by double stages.

A very effective acid elevator, made by Paul Schuetze & Co. of Oggersheim, Germany, and supplied by Messrs. Bornett & Co., of London, is now being largely used wherever acids or other liquors are to be raised.

The mechanism is entirely enclosed, stuffing boxes and other parts subject to wear and tear being dispensed with. When the supply of liquid ceases, the elevator simply stops working, and starts of its own accord as soon as the feeding tank begins to fill. In the same way, the elevator stops if the supply of compressed air or steam should fail, and re-starts immediately the required pressure is available.

These elevators work with expansion, and therefore consume only such quantity of compressed air or steam as corresponds to the height of the lift. The higher the pressure of the compressed air applied, the smaller is the volume consumed.

The liquid flows by gravitation through a check-valve into the elevator. During this period the dead weight of a double float (consisting of two rigidly connected balls) acts on a lever in such a manner that the compressed air (or steam) inlet is kept closed, whilst the outlet valve is open, allowing the air displaced by the liquid to escape. When the liquid reaches the upper part of the upper ball, the float rises, whereby the air

outlet is closed, and the air inlet valve opened. The compressed air then presses upon the surface of the liquid, which is forced through the delivery pipe. When the surface of the liquid reaches the lower ball, the float sinks, closing the air inlet valve. The compressed air expands until the egg is nearly emptied, but, before the air can enter the delivery pipe, the air outlet valve opens, and the cycle of operations is repeated.

No air escapes through the delivery pipe, which need not be vertical, but may be inclined at any angle, and may be partly horizontal. The pressure of the compressed air or steam applied may vary between 30 and 70 lbs. per square inch without interfering with the regular working of the apparatus. If required, the elevator can be constructed in such a manner as to allow the pressure of the compressed air to vary within wider limits.

The construction of the float shown allows the specific gravity of the liquor to vary by about 60 degrees Tw., so that an elevator constructed to raise liquor of an average specific gravity of say 1·65 will continue to work as long as the specific gravity does not fall below 1·5 and does not rise above 1·8. A slight modification of the design allows unlimited variation of the specific gravity without interrupting the continuous working.

The elevator performs from 30 to 60 operations per hour, according to the varying circumstances. As the quantity of liquid discharged at each operation is always the same, the daily or weekly output can be controlled by means of a counting apparatus which registers the number of pulsations.

These elevators are constructed of various materials; for sulphuric acid of at least 110 degrees Tw., of plain cast-iron; if for Gay-Lussac and Glover-Tower acid, of cast-iron, partly lead-lined, for cold or moderately warm liquors, of cast-iron, completely lead-lined, for hot liquors, of wrought iron, homogeneously leaded; for fatty acids, of copper, and for hydrochloric and nitric acid, of earthenware in iron casing

The following table shows the minimum pressure of compressed air or steam required under the different working conditions. The pressure stated leaves an ample margin for friction in the delivery pipe and for slight variations of the specific gravity

MINIMUM PRESSURE IN LBS. PER SQ. INCH.

Height of Lift, calculated from the bottom of the elevator, in feet.	Specific Gravity.								
	1·1	1·2	1·3	1·4	1·5	1·6	1·7	1·8	1·9
15	16	17	18	19	19	20	21	22	23
20	18	20	21	22	23	24	25	26	27
25	21	23	24	25	26	27	28	29	30
30	24	26	28	29	30	32	33	34	35
35	27	29	31	32	34	35	36	38	40
40	30	31	33	35	36	38	40	42	44
45	32	34	36	38	40	42	44	46	48
50	34	37	39	41	43	45	47	49	52
55	37	39	41	44	43	48	51	53	56
60	40	42	44	47	49	52	55	57	60

The Filter-press.

The filter-press is one of the most familiar and useful pieces of plant to be found in a chemical works. As perfected by A. L. G. Dehne, of Halle, Germany, it is in universal use, and, therefore, some detailed description of the construction and working of the various types of apparatus is here given. The sole agents in Great Britain for Dehne's filter-presses are Messrs. C Harzer & Co., of Finsbury Pavement House, London, E.C.

Filter-presses are used wherever solids and liquids have to be separated. They replace, in most cases to great advantage, all other devices for filtration, elimination, or washing of materials. The characteristics of Dehne's filter-press are (1) To give the largest possible filtering surface in the smallest possible space. (2) The facility of forcing the liquid part of the material through the filtering medium (cloth) by the most suitable pressure, from a slight gravitation pressure up to 140 lb. per square inch, or even higher (3) The easy handling of the press.

The filter-press consists of a number of strong corrugated iron plates with a hole in the middle, and the planed margins somewhat raised above the corrugations. The plates are covered on both sides with filter-cloth, which is fixed round the holes. The plates are tightened one against another, so that by means of the raised margin a hollow space is created between each pair of plates, which, under pressure, and assisted by the packing of the filter-cloth (the end plate has no hole), is effectually shut off from the outside

The liquor to be filtered is forced through the hole in the first plate, and enters (after the air has been allowed to escape), filling all the hollow spaces between the plates. As the pressure on the liquor continues the latter is forced through the filter-cloth, leaving and accumulating all solid matter (the impurities or the material to be separated) in the filter-chambers between the plates. After having passed through the cloth the liquor, now clear, runs down the corrugations and finds its exit through a channel to the outside of the plates. When the accumulated solids have filled all the hollow spaces (about two-thirds of the space occupied by the whole press), the shutting arrangement of the press is loosened, the plates are separated, the cakes of solids allowed to drop out, the plates re-tightened, and the process re-started.

Two chief methods of construction are employed: (1) Chamber-presses, in which the filter-chambers are formed by the raised margins referred to; and (2), frame-presses, in which the margins of the plates are on the same level as the filtering surface, and in which the filter-chambers are formed by means of hollow frames inserted so that filter-plates and frames run alternately throughout the entire length of the press.

The filter-press is used for (1) Separating solids from liquids; (2) clarifying liquors, (3) washing substances and freeing them from objectionable soluble admixtures, and (4) extracting substances.

The parts of a press which come into contact with the liquors to be filtered are made either in iron, wood, gun-metal, hard lead, tin, or iron coated with vulcanite. Iron filter-presses are preferable, on account of their durability, in all cases where there is no objection to the material to be treated coming into contact with iron or minute quantities of its oxides.

Wooden filter-presses are made of iron with wooden head-plates bolted on to them, and the rest of the plates in wood, with wooden taps, etc The channels through the iron headpiece, valves, etc., are either made of gun-metal or iron homogeneously lined with some suitable material (hard lead, tin, or indiarubber), so that the material to be dealt with comes into contact with nothing but wood and a suitable metal. The wooden parts are usually made of carefully selected pitch-pine, but they may be constructed of oak, teak, etc., if desired Dehne's plates are so

FIG. 47.—Filter-press, by A. L. G. Dehne.

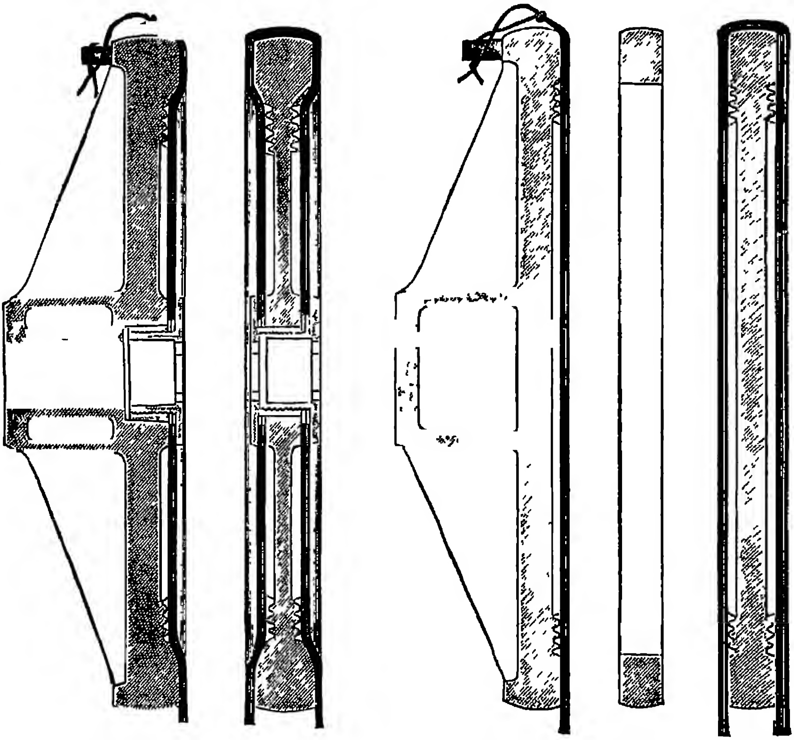
designed that they are given the utmost strength. The central filtering surface having a margin built round it, the whole of the plate (filtering surface and margin) is made up of several vertical sections which are held together by horizontal bolts at the top and bottom. It is, therefore, a physical impossibility for the top and bottom of a plate to be blown out. The wear and tear of the wooden parts is very slight, and they can also be renewed at small expense when necessary.

In the chamber-press the cakes drop out with very little assistance, as soon as the press is opened and the plates separated. In the frame-press, the cakes forming within the intermediate frames can either be lifted right out of the press in the frames or knocked out Frame-presses are, therefore, not suitable for substances not forming a solid cake. For materials of this kind chamber-presses with the feed channel at the bottom left-hand corner should be used, as with this type the press can be drained before it is opened. In frame-presses the feed channel is situated outside the filtering surface, with a channel leading to the interior of the frame. In all cases, therefore, where the material is of such a nature that it is likely to block this comparatively narrow channel, the chamber-presses are most suitable. On the other hand, where there is no fear of blocking this small channel, the frame-press has many advantages, as the whole filtering surface is available for work, and the fixing of the filtering cloths is very much simpler.

The following illustrations show the various methods of fixing the filter-cloths. Fig. 48 (A) shows the headplate and plate of a chamber-press. It will be seen that the cloth is simply hung over the plate, and clipped at the feed hole with a union screw. This is a most convenient method, and is far more simple than the usual one, shown in Fig. 49 (C), viz., joining two cloths together at the centre feed hole with a short cloth pipe, pulling one cloth through the feed hole, and then tying the two together at the top. Fig. 48 (B) shows the method for frame presses. In this case, the cloth is simply hung over the plate, and requires no fixing whatever. In cases where the plates have channel flaps outside, these must be provided with a packing which is the same thickness as the filter-cloth. This is effected either by fitting the channel flap with a cuff made of the same material and thickness as the filter-cloth used (see Figs. 49 A and 49 B) or

by providing these channel flaps with india-rubber tightening rings. The latter arrangement is by far the most convenient. The channel flaps have a circular groove cut round the channel holes in which india-rubber cloth-covered rings are inserted. These make a perfectly tight joint and the rings last a long time, and can be easily renewed at small cost.

The standard thickness of the cakes is 1 inch to $1\frac{1}{8}$ inches. If

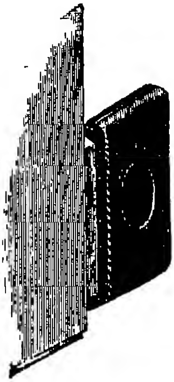


A.—Headpiece Plate. B.—Headpiece Frame Plate.

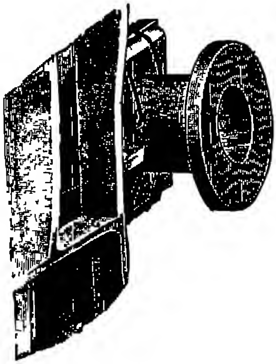
FIG. 48.—Dehne's Filter-press. Methods of Fixing Cloths.

desired, the thickness can be reduced or increased. The more easily the material filters the thicker may be the cake. In the case of Dehne's washing presses, experience has shown that it is not advisable to increase the thickness above the standard except in very rare cases, any gain by the thicker cakes in the filling of the press being more than counteracted by the disproportionately longer time required for the thorough washing.

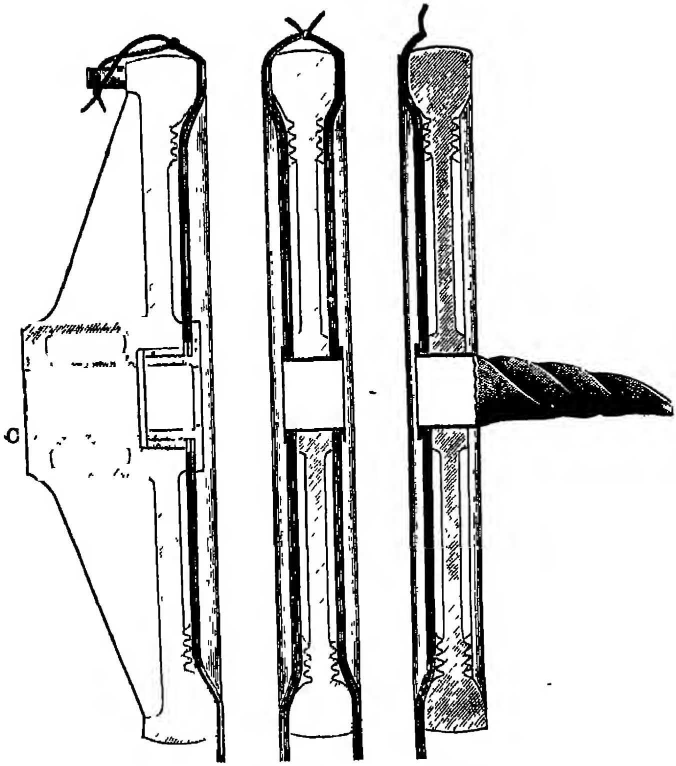
The proper choice of the most suitable filter-cloth is one of



A.—Channel Flap.



B.—Channel Flap of Headpiece.



Headpiece. Plate Plate.

FIG. 49.—Dehne's Filter-press: Methods of Fixing Cloths.

the most important factors upon which the result of filtration depends. The guiding principle will be best apparent if we regard the filter cloth as a sieve with very fine meshes. The meshes should be just narrow enough to hold back the particles which it is desired should be retained. If the meshes are smaller (i.e., the cloth denser than necessary) the output of the press will naturally be reduced. The exact determination of the most suitable cloth can only be arrived at by actual experience. The usual raw material for the cloth is cotton; where, however, acid liquors are being dealt with, woollen cloths will probably be necessary.

The provision of taps to each plate gives the advantage of allowing a perfect control over each filter-chamber. If something is wrong in one chamber (the cloth torn or shifted), which will be noticed by the one tap only running turbid, this tap may be shut off and the working of the press continued.

Presses with closed efflux channel are used if the clear liquor leaving the press is conducted under pressure to a higher tank, or if the liquor is volatile. The disadvantage is that no control over the separate chambers is afforded.

Dehne's presses are provided with two washing systems, the thorough-extraction system being a novel improvement on the old simple washing arrangement, which only partly attains its end of washing the soluble admixtures out of the cakes. The simple washing arrangement is still provided in all cases where only a partial removal of the soluble admixture is required. It consists of one channel through which the wash-water finds its way into every alternate plate, passes through the cake and out of the open tap of the next plate. Only part of the cake is effectually washed, and there is a great tendency for the water to form a channel in the cakes and not to wash the other parts. This has led to the construction of the thorough extraction system, the only device which ensures an absolute and quick extraction of all soluble matter with the least quantity of water or other suitable solvent.

After the formation of the cakes, the taps are all closed. The wash-water is now forced under a suitable pressure (preferably a somewhat higher pressure than the one at which the press has been filling) into channel *b*, and is distributed over the filtering surface of the alternate plates (one having a channel

to the inside, the next none). It is now forced simultaneously over the whole surface of the cake to penetrate the cloth, the cake, the next cloth, to collect behind the filter-cloth of the next plate, and find its exit on the top of that plate into the united efflux wash channel *d* of every alternate plate: *c* is the channel for the escape of the air. The arrangement of these channels compels the wash water to penetrate every part of the cake horizontally, and to take with it every particle of soluble matter. The actual course of the thorough extraction can be controlled in two ways: (1) by the amount of water passed through the cakes, which can easily be measured by means of a graduated trough fitted with a special valve; or (2) by the control of the specific gravity of the wash-water by means of a hydrometer placed in the control apparatus.

With the assistance of the illustrations, Figs. 50 and 51, the working of presses fitted with the thorough extraction system will be very clearly shown. When feeding the press, the valve *a*, controlling the feed channel, and the taps *i* should be open, all other valves being closed.

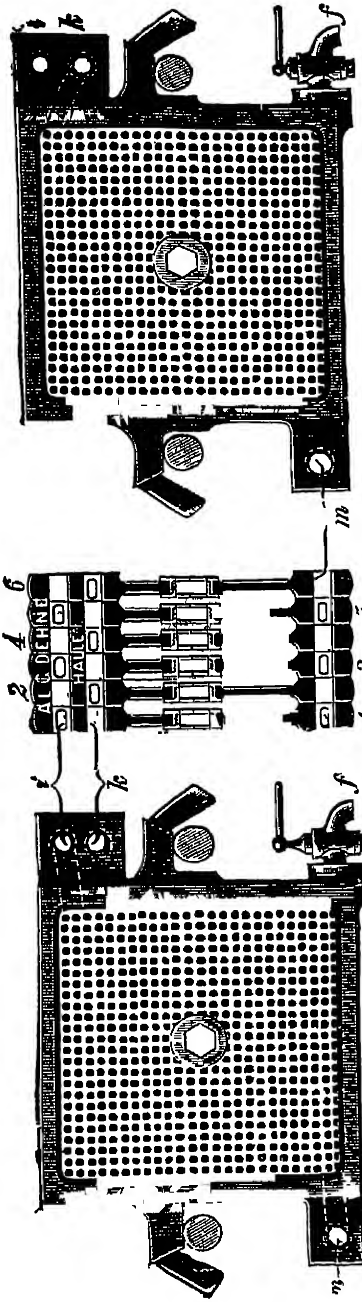
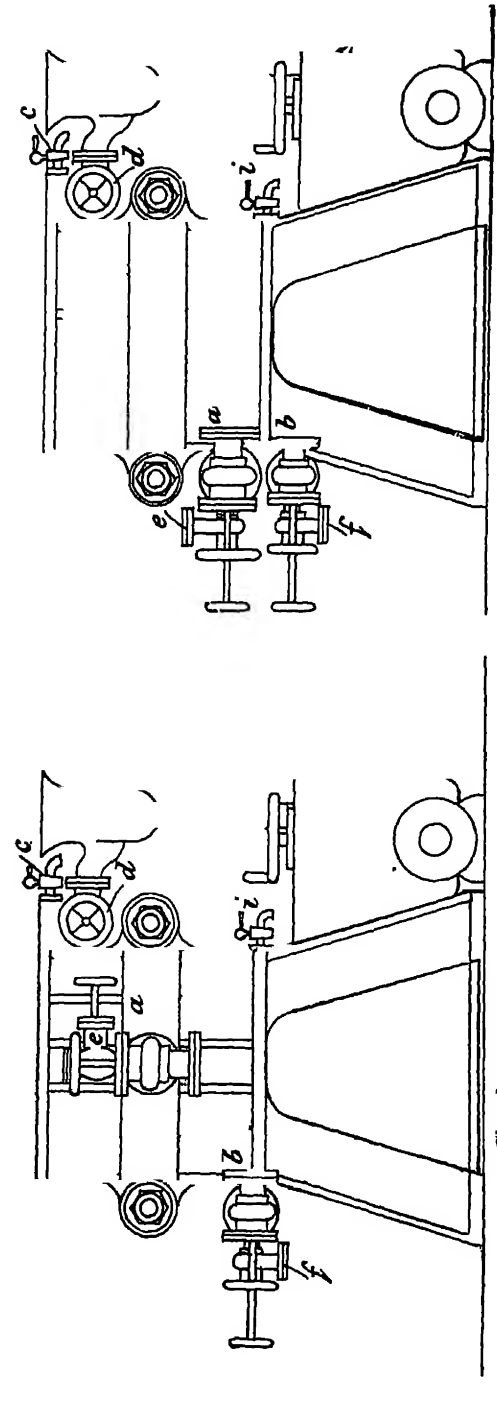


Fig. 50.—Details of Thorough Extraction Filter-press.



Frame-presses.

Chamber-presses.

FIG. 51.—Dehne's Filter-press: Thorough Extraction System

As soon as the press is filled with cake, the feeding is stopped and the washing operation started. For this, the valve *a* and the taps *i* are closed. Valve *b* and the air tap *c* are then opened, but as soon as the wash-water commences to run from the tap *c*, this should be closed and valve *d* opened. For the remainder of the washing operation, only valves *b* and *d* should remain open. On the press are supplementary valves *e* (on the feed-channel) and *f* (on the wash water inlet channel). These can be used for various purposes, such as aerating or steaming the cakes, passing hot air through, etc. The valve *f* can also be used for draining purposes if by any chance the press should not be full of cake and needs emptying before it is opened.

It is a principle of filter-press design that the press should be square in form, in order to ensure the most economical use of filtering surface, and that the most easily cleaned and efficient surface is one consisting of fine ribs or corrugations. Providing that care is taken to give the corrugations sufficient depth to prevent the filter-cloths from sagging to the bottom when under pressure, and that the ribs or corrugations are smooth and carefully rounded, this will be found to form the most effective practice. The filter-cloth must not be regarded as the principal filtering medium, but only as the foundation upon which the real filtration is based. As the operation progresses, there grows gradually a stratum of the matter at first arrested by the cloth, and the liquor following has thus to pass through an increasing thickness of solids in addition to the cloth. Thus there are cases where satisfactory filtration is only obtained after the press has been in operation for some time. Given a uniform material, the cake should form on both sides of the filter-cloth alike, and in fairly strict uniformity. The more porous the filter-bed, the quicker will be the formation of the cakes of matter arrested. This cake, again, varies in degrees of solidity or density according to the degree of fineness of the particles forming it. It follows, therefore, that the more open the filter-bed the sooner will a cake of a given thickness be formed, due consideration being made for the pressure employed. The pressure must be arranged according to the porosity of the cake, in order to ensure the maximum of filtered liquor in any given time.

Again, it is of the utmost importance that the continuity of

pressure should be recognized in defining the most acceptable form of working. The pressure may, at intervals, be slightly increased, but should not be allowed to fluctuate or become jerky, which may be obviated by a large air vessel being used or the employment of the montejus. The elimination of gluey and slimy substances, and small particles of other solids, necessitates a porous filter-bed to ensure prolonged filtration. In the

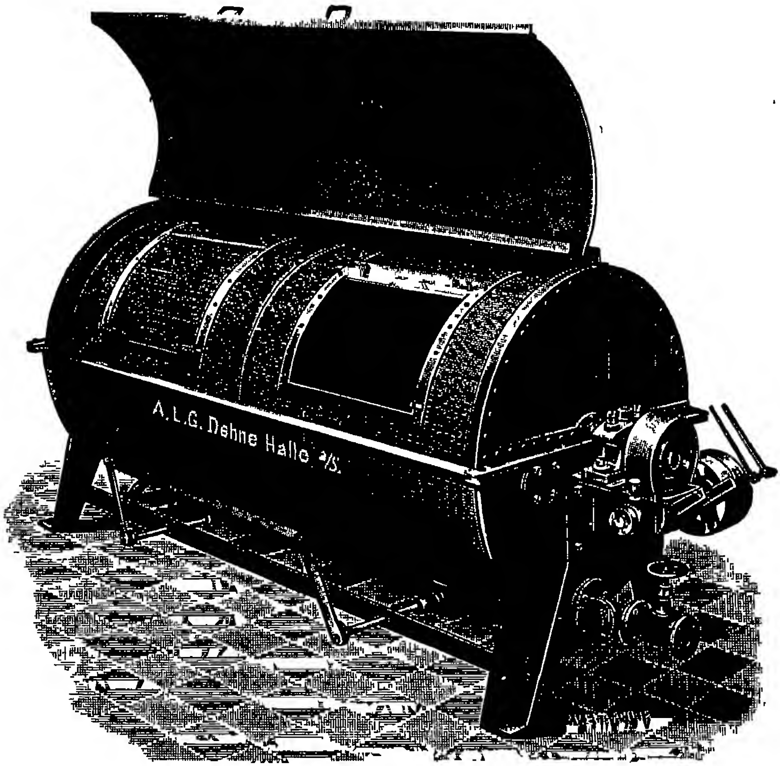


FIG. 52.—Filter-cloth Washing Machine

case of very fine particles, these are forced into the pores of the cloth, and thus retard or entirely stop the work; with these a slight uniform pressure is obtained by feeding the liquor entering the filter from a tank placed a few feet only above the inlet.

Where neither iron nor wood can be employed, the filter-press is constructed in such a manner that all the parts which come in contact with the material being worked are of iron

coated with vulcanite, hardened lead, gun-metal, or tin. For such liquids as ether or ammonia, for instance, in order to prevent the vapours escaping, a sealed condensing cover is provided.

In the case of materials that only require a low pressure, such as oils, where strong construction is not required, filter-presses tested to 28 lb. to the square inch may be obtained. So also for oil filtration, presses with two outlet taps enable oil to be fed by gravitation (the top row of taps being used first)

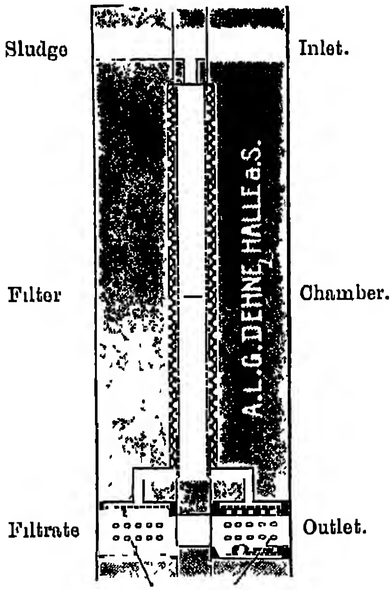


FIG. 53 —Check Filter.

into the presses. For increased pressure, a bottom row of taps, and, if necessary, a pump, may be employed

The washing of filter-cloths is usually done by hand, by means of a fibre brush and water, for which purpose the cloths are spread out singly on a board. This tedious manual labour can in most cases be dispensed with by the use of Dehne's cloth washing machine (Fig. 52) The cloths are placed in the washing cylinder, about a dozen at a time, and the cylinder is then set in motion by belt transmission, when the water in the trough of the machine circulates through the cylinder and

washes the dirt out of the cloths. The inlet and outlet of the water are regulated by stop valves The water can, if necessary, be heated in the machine by the admission of steam.

With filter-presses provided with taps, the action of the filtrate can be watched, and, if necessary, a muddy chamber can be stopped by closing the efflux tap controlling it, so that the clear filtrate of the other chambers may not be diluted. But it is better still if the taps themselves are self-acting, and made in such a way that they act as small check-filters; they will clear the first runnings and if, for any reason, during an operation, the filtrate becomes cloudy, they will automatically close that particular chamber altogether.

With filter-presses which have a united efflux channel, the filtrate cannot be watched at all, and it is impossible to tell which chamber is running cloudy. It is then necessary to stop the whole press. In such filter-presses, check-filters can be inserted in the channels of the various chambers, and so allow only a clear filtrate to pass. If a filter-cloth is torn, these check-filters automatically close the chamber.

The Osmose or Dialysis Apparatus.

These machines are constructed for the practical employment of the physical principle of diffusion, osmosis or dialysis.

If two different miscible liquors which have no chemical action one upon the other are allowed to come into contact with each other, the effect of the natural attraction of their respective molecules solely, without any agitation or other influence, causes a constant exchange of molecules between the two liquors, until they are thoroughly amalgamated into one, which is absolutely homogeneous. A similar process takes place if the two liquors are separated by an animal or vegetable membrane, capable of being saturated with the respective liquors (in this apparatus parchment paper). The membrane forms a sieve with very minute meshes According to the size of them, some molecules will pass this sieve very readily and quickly, others very slowly, and some not at all. Diffusible and non-diffusible bodies can thus be differentiated, and as experience has shown that the former possess, almost without exception, the characteristic of either being crystallizable, or at least to form crystallizable chemical combinations, the former

are called "crystalloids" and the latter, mostly of a gluey, slimy character, "colloids".

The quality of the crystalloids to diffuse is made use of in their separation from the colloids. If the alternate chambers of the apparatus are constantly supplied with fresh water, it will be seen that in the proportion of crystalloids and colloids in the mother-liquor, the former will be constantly diminished and increased in watery solution. As mentioned, the rate of diffusion must vary with the size of the molecules—common salt diffuses twice and sulphuric acid three times as quickly as sugar. This difference in the speed of diffusion is made use of for the separation of different crystalloids.

The skeleton of the dialysis apparatus is similar to that of a filter-press. It contains a number of wooden frames, which are alternately constructed so as to hold the two different liquors. To prevent the frames from being wrongly placed, the tops are alternately flat and pointed, with triangular handles on one side and flat on the other. The parchment-paper is hung over the pointed frame only.

Corresponding holes in the frames form channels through which the two liquors, one generally water, introduced through two funnels, are conducted into the alternate chambers, through which they constantly pass at a slow rate, leaving the apparatus by the control pipes, in which a hydrometer is placed.

Every twenty-four to thirty hours the lever on the fixed head-piece is turned, which has the effect of causing one liquor to enter the chamber previously occupied by the other. This is done in order to make the liquor pass through the parchment-paper in the reverse way. Every three or four days the apparatus, if in constant use, is cleaned by passing some acidulated water through. A change of paper is usually required every six or seven days.

SCHULER'S POROUS FILTER PLATES

As a filtering medium for valves, vats, etc., Schuler's porous filter plates, as supplied by Messrs S. Bornett & Co., are now in extensive use. These plates were originally made for acid liquors and coarse precipitates, and, as such, met with great and increasing favour. The manufacture of them has developed gradually, and by continual improvement they can now be

supplied as suitable for either the finest precipitates or for acid and alkaline liquors. The plate, rebated around the top of the filtering surface, and the consequent grooves when the stones are together, are filled with jointing material to enable them to resist, like the filter plates, the effects of liquors of a similar character. Portland cement, lead, or a mixture of sulphur and graphite, and similar substances may be used, and will be found, if required, to form a suitable jointing material.

In order to avoid clogging, very fine porosity marks the plate surface, in such a way (gradually increasing downwards) that there is no obstruction to the flow of the filtrate by the lower portion of the plate, which serves merely as a support, and gives the filtering layer strength and cohesion. In certain instances, at the bottom of the plate, holes are provided almost to the filtering plate, and these assist in the carrying-off.

If they are intended to be used on a double bottom, the bottom of the plates is flat, but if the plates are grooved on the underside, the false bottom is unnecessary. By the pressure under which filtration is carried on, the section of these grooves is determined, being deepest for the slightest pressure and *vice versa*.

The plates possess a number of important improvements upon many makes now upon the market. Their special porosity excludes the very finest particles of solid matter, therefore they do not "clog," and washing is obviated, with a considerable saving in labour, and also cost, because duplicates need not be provided. For the treatment of alkaline and corrosive liquors they have found a very wide use, which is likely to become general in works where such liquors have to be dealt with, and their employment is also extending to neutral liquors, a perfectly bright filtrate resulting from the very beginning of filtration.

The porous filter-plate method may be utilized in all the best-known types of filters, though specially designed pressure filters, under pressure, are probably the most completely satisfactory method In cases where a vacuum is employed for filtering or other purposes, vacuum filters may be used.

Pressure Filters for Acid Liquors

Bornett's pressure filters for the filtration of acid, alkaline and corrosive liquors of all kinds by means of porous filter-plates,

are also very useful. The advantages of this practically indestructible filtering material, which can be used even for the finest precipitates without clogging, has already been indicated.

Both vertical and horizontal types of these filters can be obtained. For small outputs up to 9 square feet of filtering surface, the vertical filter is recommended. The outer casing contains the filter-pot, in which are placed the filter-plates. During filtration, the pot is filled with the liquor under treatment, the casing is closed, and compressed air is admitted. The pot is then entirely surrounded by compressed air, and is not exposed to any unbalanced pressure, not even on the bottom, as the filter-plates rest directly on the latter. The pot, which alone comes into contact with the liquor, can therefore be made from material of low tensile strength, i.e., lead, tin, stoneware, or wood, as any deformation is impossible, owing to the system of balancing the pressure.

According to the working pressure and temperature, the casing is made of cast iron or steel, and, if necessary, is protected from vapours by paint or by a lining. The joint round the outlet from the pot is made by a rubber ring.

The filters are used in the following manner. At the beginning of each operation, the pot is filled with the liquor to be filtered, the filter is closed and compressed air is admitted; or they can be used continuously by pumping in a quantity of turbid liquor corresponding to the amount of filtrate discharged. The consumption of compressed air is very small, as this is only admitted at the beginning of each operation, and remains in the filter during filtration and washing. The wash-water is introduced in such a fashion that it flows down the wall of the pot, and does not mix with the mother-liquor, which is generally of higher specific gravity. The mother-liquor is therefore displaced in the shortest possible time, and an extremely small quantity of water is sufficient for complete washing. The filters are fitted with air inlet and air outlet valves, pressure gauge, safety valve, and with inspection glasses which permit the attendant to watch the progress of filtration and washing from time to time. The vertical pressure filters of this type are supplied in different sizes up to a pressure of about 12 square feet. Where a larger filtering area is required, the horizontal filter is recommended.

The horizontal filter is formed by a number of filter trays which are arranged in a casing. The filter-plates rest on the bottom of each tray, in the same way as in the vertical filter. The drainage channels formed by the corrugations at the bottom of the plates discharge, however, into the lateral outlet pipes. In this type also, it is only the trays that are filled with liquor, which does not come into contact with the outer casing, and the trays may, therefore, again be made of lead, stone-ware, wood, or some other material capable of resisting the action of the liquor.

To facilitate the removal of the residue, each tray is provided with two cross-bars running on wheels. When the tray is withdrawn from the casing, the front bar rests on a bracket placed on the cover, while the bar at the inner end runs on rails fixed in the casing. When the tray is to be withdrawn, it is coupled to the door by means of a hook in the case of the top-most tray. As soon as the tray has been withdrawn, it can be tilted to facilitate rapid removal of the residue. The cover is closed either by bolts or by means of a cross-head and screw. While the filter is closed, the cover presses on the tray, so that the rubber joint-rings placed on the outlet pipes are compressed against the back of the casing and make the joint during working. The joint between the casing and the cover is made by a rubber strip held in a dove-tailed groove, which, like the rubber rings on the outlets, lasts for a long time, as it does not come into contact with the liquor.

The method of working is similar to that used with the vertical filter. Sludges which can be pumped only with difficulty are filled into the trays before the casing is closed. If the liquor can be pumped without trouble, the filter is used continuously, and in a filter provided with a number of trays arranged one above the other, the liquor may be fed separately to each tray, or it may be pumped into the top tray only, and overflows through suitable large pipes into the others. The progress of the operation in each tray can be watched by suitably placed inspection glasses.

One man is sufficient for attending to all operations, i e., charging, emptying and closing, even with filters of the largest size, which may have a filtering surface of 200 square feet and a capacity up to 1000 gallons.

The porous filter plates produce, even at a high pressure, a clear filtrate from the start. For this reason it is not necessary to watch the filtrate, and the outlets can be combined into a common discharge pipe without any drawback. In this case the pressure filter also acts as a forcing receiver, and the filtrate may be discharged at any higher level.

Fused Silica Ware or "Vitreosil".

A substance which is deservedly finding increasing use in chemical works is the fused silica ware produced by the Thermal Syndicate, Limited, of Wallsend-on-Tyne. By the aid of the electric furnace the manufacture of "Vitreosil" has been suc-

Fig. 54.—"Vitreosil" Pipes.

cessfully developed, and a valuable range of articles is now available for use in connection with chemical plant which simplifies many of the problems confronting the chemical engineer.

The principal properties of vitreosil are its great resistance to heat and acids. It is amongst the most refractory of materials, melting at about the same temperature as platinum (between 1700° C. and 1800° C.). The co-efficient of expansion of fused silica is extremely small, being about one-seventeenth of that of glass. In consequence of this small co-efficient it is possible to subject vitreosil to rapid changes of temperature without any danger of breakage. The material is unaffected by acids, with the exception of hydrofluoric, and, at high temperatures, phosphoric; the action of phosphoric acid on silica only commences above 400° C., so that for all ordinary purposes it can be safely

used with this acid. Sulphuric, nitric, and hydrochloric acids, or a mixture of acids, such as aqua-regia, have absolutely no action on the material.

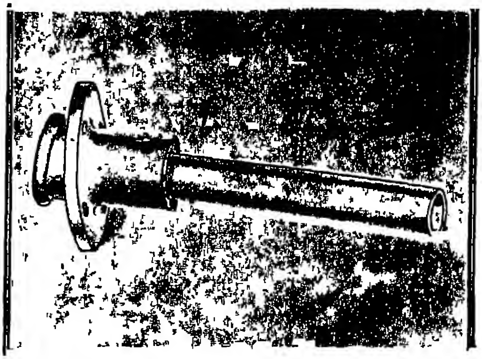


FIG 55.

Vitreosil is now being employed in the construction of plant for the manufacture and concentration of sulphuric acid, in place of lead, porcelain, volvic lava, and platinum. One of the weak points of vitriol plants is the pipe used for conveying acid into

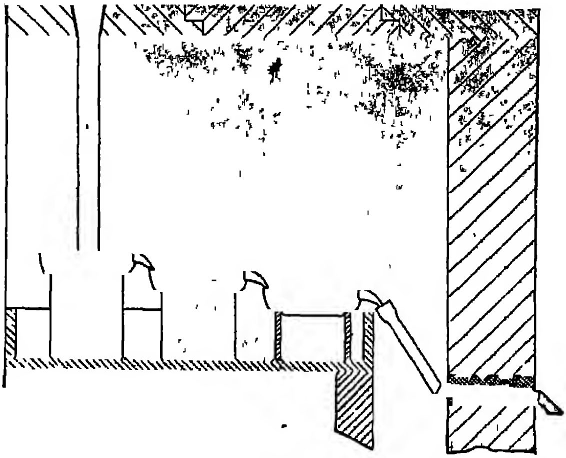


FIG. 56.

the nitre-pot. This pipe, usually made of iron, but sometimes of earthenware, is soon affected by the high temperature and corrosive action of the acid, and frequent renewals are necessary. A vitreosil pipe, shown in Fig. 55, with cast-iron pro-

tection socket, has been substituted in many English chemical works for the former iron pipes, and has proved most successful.

Instead of the usual nitre-oven the arrangement illustrated in Fig. 56 may sometimes be adopted with advantage. This consists of a series of shallow-lipped basins, which are placed in a chamber at the end of the burners. Liquid nitric acid is fed from the top (as shown) or through the side walls, according to the manner in which the plant is arranged.

The acid is evaporated by the hot burner gases, and passes through the Glover tower into the chambers in the usual way. This method allows the amount of "nitre" introduced to be easily varied without disorganizing the process.

The lead lips and gutters of the Glover towers are seriously

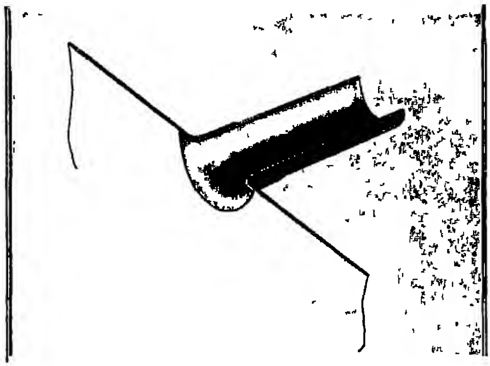


FIG. 57.

affected by the hot acid and by the scouring action of fine particles of coke or disintegrated packing from the tower. Additional false lead lips and brick linings are resorted to in some cases to increase the life of these parts, but with only moderate success Vitreosil lips and gutters (Figs. 57 and 58) have entirely overcome these difficulties, as the material is quite proof against scouring, and is, of course, unaffected by the acid. Vitreosil siphon pipes (Fig. 59) may be used to draw off the acid when a Glover tower is not luted in the usual way.

The efficient concentration of sulphuric acid has always presented difficulties to chemical manufacturers, mainly owing to the failure of the materials of which the plant has been constructed. That it is a question of materials, is proved by the

fact that costly plants have been installed in which the concentration is carried out in vessels made of platinum, or platinum-iridium alloys. Attempts have been made from time to time to construct continuous concentrators, using glass, enamelled iron, or porcelain for the concentrator units. The frequent replace-

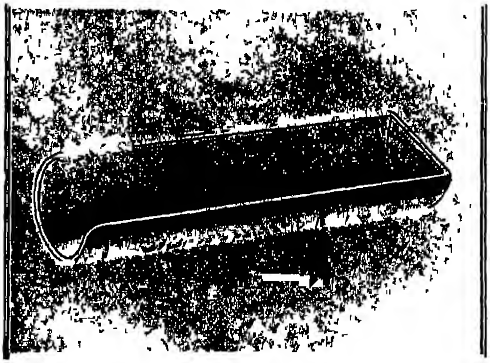


FIG. 58.

ments necessary, either through breakage of the vessels by heat, or on account of the action of the acid on them, has been a serious item in the upkeep of such plants.

The possibility of using vitreosil vessels in place of porcelain, etc., for these cascade processes, immediately appealed to acid makers when the properties of the material became known. Trials were made at several works in 1907 with vitreosil beakers and basins, and successful results were obtained. It was found that there was no necessity to protect the vessels from the flame by means of fireclay slabs or pots filled with sand, as they could be exposed to direct firing without danger. The result was an increased output of finished acid with a decreased consumption of fuel, and at the same time the breakage of vessels was very largely reduced.

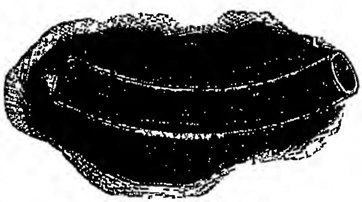


FIG. 59.

Extensive use has been made of vitreosil basins, one of which is shown in Fig. 60, for cascade concentrators, over 600 being in daily use in Great Britain, while a larger number are in opera-

tion on the Continent. The plants working in Great Britain only, at the present time, represent an output of about 22,000 tons of 168 degrees Tw. acid per annum.

A silica basin plant combined with lead pre-heating pans is very efficient. A test over a period of four months on one plant gave the fuel consumed as 15 per cent of the weight of finished acid. This was with a concentration of 168 degrees Tw., starting with acid of 106 degrees Tw.—110 degrees Tw. The output of a forty-basin plant is approximately 4 tons of 168 degrees Tw. acid per day.

Beakers for the Webb, Dyson, and similar systems are also

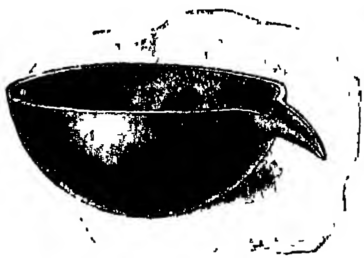


FIG. 60.

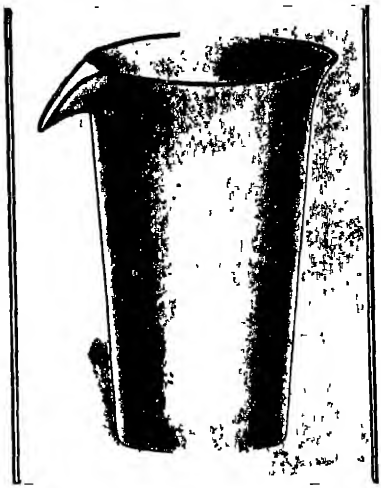


FIG. 61.

made. The following paragraph from the Forty-fifth Annual Report of the Chief Inspector of Alkali Works refers to a concentration plant using vitreosil beakers. "Experiments with specially designed 'fused silica' vessels, instead of porcelain ones, have been made at one work. The manager is so well satisfied with this material for the purpose of rectifying sulphuric acid that he has now substituted it for the porcelain vessels through the whole of the plant."

In the manufacture of nitric acid, vitreosil has not yet been so extensively used as in the sulphuric acid industry. This is mainly due to the fact that the retorts, receivers, etc., now in use are somewhat larger than can be made at present. Smaller

apparatus, however, such as still heads for Valentiner's apparatus (Fig. 62), Guttmann still heads, built-up pipe ranges, and condensers, are manufactured. The disadvantage of stoneware for these purposes is its liability to break through temperature changes, which is entirely obviated by the use of vitreosil.

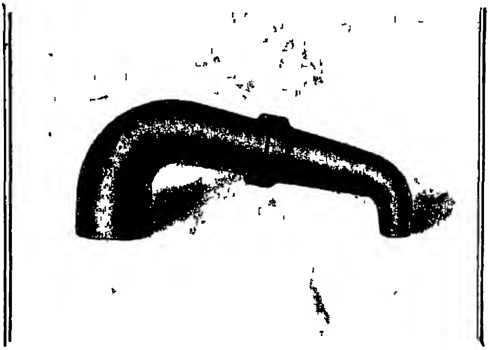


FIG. 62.

Pipes for condensers, etc., are usually supplied with socket joints, the joint being preferably made with asbestos cord and an acid-proof cement. Flanged pipes are not practicable in vitreosil, as the expansion or contraction of the bolts or clamps

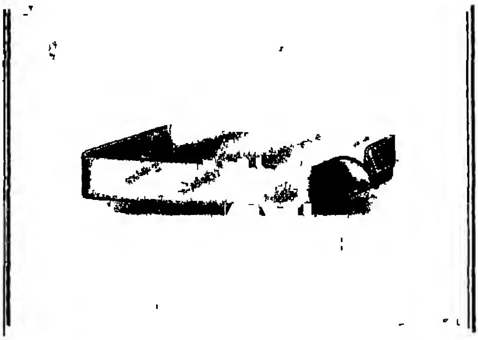


FIG. 63.

is liable to produce a strain at the flange, and so cause breakage. Pipes can also be obtained with tapered ends or a uniform taper in the length. For certain purposes tapered joints offer advantages over sockets.

The small co-efficient of expansion of fused silica must

always be borne in mind when apparatus is constructed in which it is in contact with other materials. Sufficient play must be given to the silica to prevent it being compressed by the other parts when the apparatus is heated.

A recent addition to the vitreosil products is a shallow tray, Fig 63, as illustrated. These trays present special advantages for cascade processes on account of the large heating surface they offer to the fire gases.

Another system of concentration on which advantage has been taken of the properties of vitreosil is the Kessler apparatus. The parts of this plant which are at present made in vitreosil

"Culotte."

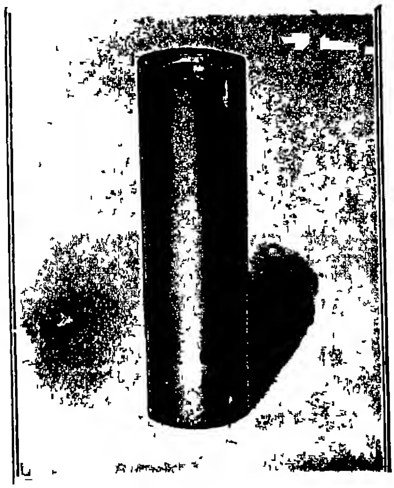


FIG. 64.

are the leading-in-pipe, centre pipe, culottes and supports. Experience has proved that volvic lava has a tendency to gradually disintegrate, especially where the working of the plant is intermittent, whereas vitreosil is entirely unaffected. The greatest trouble in the working of this plant is experienced by the frequent breakages of the porcelain culottes. After a series of trials a successful culotte has been produced in vitreosil. These culottes, are slightly modified from the porcelain shape, but are quite standard as regards fitting into existing plateaux.

Apparatus for cooling the acid from concentrators are made in two types, Figs. 64 and 65. The pot type cooler, Fig. 64,

consists of an outer lipped vessel and an inner centre pipe. The lipped vessel is seated in an iron or lead tank through which water is circulated. The hot acid enters the centre pipe, descends to the bottom, and, passing through the slots in the pipe, rises between the pipe and the walls of the vessel, where it is cooled by the circulating water outside. The capacity of a single pot is from 1½ to 2 tons of 168 degrees Tw., per twenty-four hours, cooled from 269 degrees C. to 40 degrees C. Fig. 65 shows a coil cooler suitable for use with acids containing no suspended matter, which is highly efficient. As an example of the working of these coils for acid cooling, the following figures relating to a small coil working in conjunction with a concentrator are of interest:—

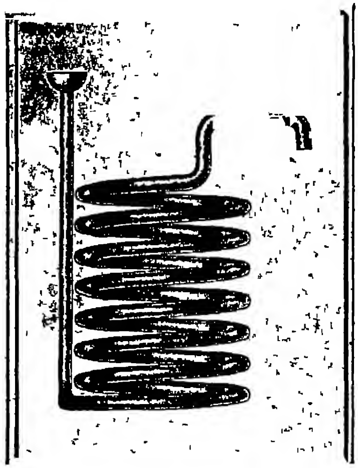


FIG. 65.

Area of coil	2·6 square feet.
Acid cooled per 24 hours	1680 lbs.
Water used per 24 hours	1100 gals.
Temperature acid entering	220 degrees C.
Temperature water entering	5 degrees C.
Temperature acid leaving	39 degrees C.
Temperature water leaving	19 degrees C.

HOMOGENEOUSLY LEAD-LINED PIPES, ETC.

Lead-lined pipes, coils, worms, etc., are most useful for making the connections in any acid plant. Such pipes, etc., made in any diameter and in lengths up to 20 feet, lead, lined inside homogeneously, are made by Messrs. Paul Schuetze & Co., of Oggersheim, the English agents for whom are Messrs. S. Bornett & Co. The same firm supply pipes, etc., coated externally, and also lead and tin-lined apparatus and vessels similarly treated. In practice, this homogeneously treated apparatus has been found most useful, and lends itself to a variety of purposes which it is scarcely necessary to enumerate.

Kestner's "Climbing-Film" Evaporator.

The evaporation of liquids is a process that has been known for many centuries; but only in recent years has a careful study been made of the principles governing its working. When film evaporation was first introduced, it was found to effect a great economy compared with any other form of evaporator then known, but it was not until the climbing film was invented that the full possibilities of this type of evaporator were realized. M. Paul Kestner, of Lille, who has had considerable experience in film evaporators, knew all their limitations, and overcame them by means of his patent climbing-film apparatus.

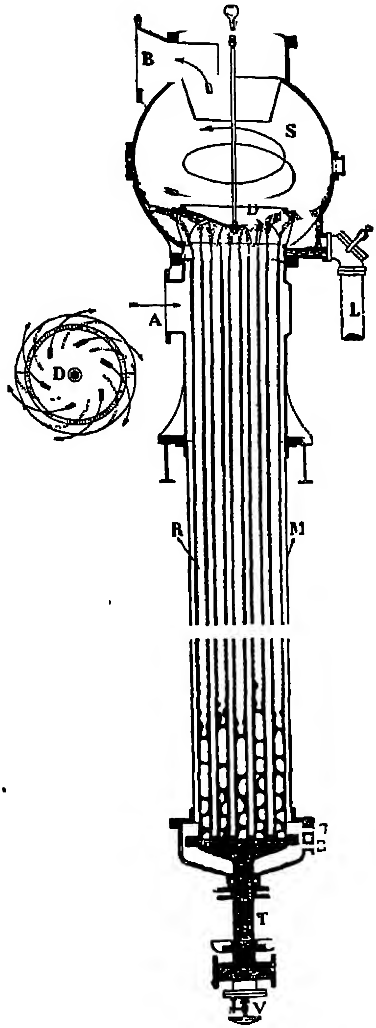


Fig. 66.—Kestner "Climbing-Film" Evaporator.

The evaporator has been styled a "climbing film" because of the climbing of the liquids in the tubes. The climbing action is shown in Fig. 66. As will be seen from this sketch, the liquid boils in the bottom of the tube and is continually climbing up the inner surfaces, while the centre acts as a passage for the steam generated. The movement of the liquid through the tube is very rapid, while the distribution over the surface of the tube is perfect. The steam generated acts as an invisible core holding the liquid close to the tube surface, while the continual movement of the liquid over this heated surface gives the circulation required to cause rapid heating and evapora-

tion. All the heating surface is of equal value for heating purposes, and the temperature is under complete control, the result being that liquids can be concentrated to any desired degree in one passage through the tubes.

The liquid to be concentrated passes through the inside of the tubes, while the steam for heating is outside the tubes, entering the shell at A. The upper casing, S, forms the separator, and contains the centrifugal baffle, D. The baffle is so designed that it prevents the particles of liquids from passing away with the steam through exhaust outlet B. The steam which exhausts at B is generated in the tubes by the heat of the steam in the shell, and which is admitted at A. When multiple effects are used the steam from B is carried to the inlet A in the shell of the second effect; while the concentrated liquid is discharged from L direct to the inlet of the second shell.

Another form of evaporator, and one which may be used for many purposes, is the direct-fire heated type. Fig. 67 gives an illustration of such an installation. The following description shows clearly the method of working: The liquid to be concentrated is contained in the tank X, and flows by gravity into the evaporator, through the pipe T. The liquid is concentrated in one passage through the tubes, and flows through the pipe L, to the tank Y. The steam generated passes through into the separator and exhausts through the opening B, from which it can be connected to heaters for heating feed-water, for concentrating in vacuum, etc., etc. In addition to this, the apparatus is designed so as to take the steam from the opening B, at a pressure up to, say, 45 lb. per square inch, so that it can be used for similar purposes. The arrangement of the flue and the passage of the gases are clearly shown. This gives a very economical working plant, as the design of the effect and arrangement of the tubes are such that all the advantages of a steam generator are obtained, as in a modern water-tube boiler.

There are many works and plants where the Rivers Pollution Acts prevents the waste liquids from being returned into rivers, and this type of evaporator, being so inexpensive in design and simple in construction, meets a want in that direction that will be appreciated by many manufacturers. It has the further advantage of being easily erected, and does not require expert mechanical knowledge to work it.

In another type of evaporator the heat from the exhaust steam on its way from the engine to the condenser is utilized. The exhaust steam from the engine is delivered into the shell of the evaporator; the heat obtained from this steam giving the heat required to produce the necessary evaporation. A slight drop in vacuum results; but at most about 2 inches. This would have little effect on the economy of the engine; but would enable concentration to be carried on at a very low cost. This necessitates an evaporator slightly different from the usual "climbing film" type. It is what is termed a downward flow apparatus, as after the usual climbing film action takes place, the steam passes through a series of down-flow tubes into the condenser. The condenser is coupled up to the exhaust opening in the evaporator, and condenses the steam thus generated, instead of being coupled direct to

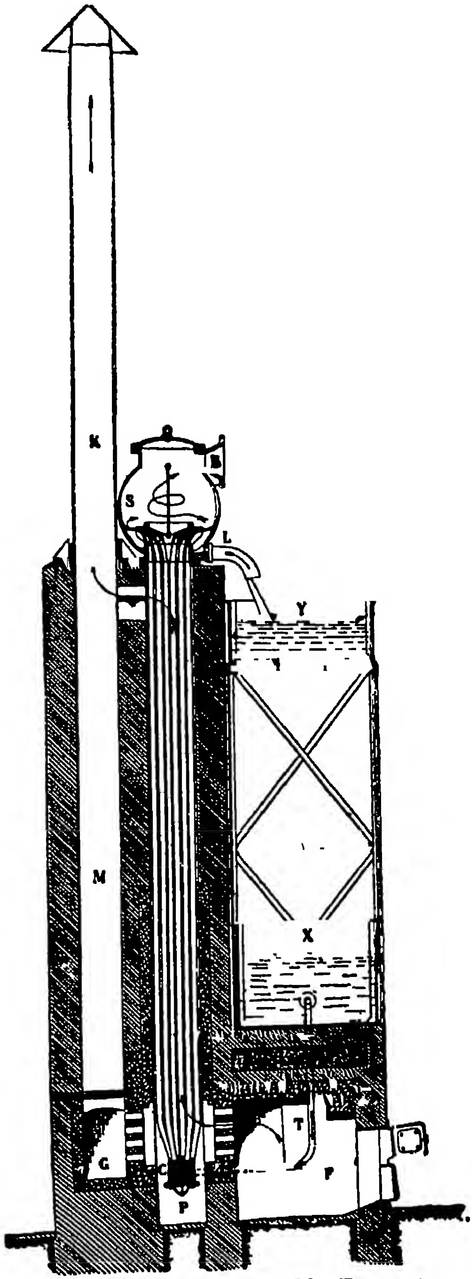


Fig. 67.—Kestner Climbing-Film Evaporator, Direct-fired Type.

the main engine. An automatic exhaust relief valve is provided so as to enable the engine to exhaust to atmosphere if required at any time.

When existing installations are overloaded, the question often arises as to the best method to extend or increase the output of the present apparatus. In such a case, the climbing-film evaporator can be added to an old-type pan. This can be carried out with any design of pan. It is usually the most satisfactory arrangement to make the Kestner the first effect; but each particular case has to be considered on its own merits, as in some instances the effects can be added in parallel with existing pans, so as to increase their heating surface and the capacity of the whole plant.

Climbing-film evaporators are usually about 30 feet high over all. They occupy very little ground space, which is most important in works near large towns.

Water-Driven Centrifugals.

The machines shown in Figs. 68 and 69 represent patent water-driven centrifugals fitted with patent interlocking gear. As will be seen from the illustrations, the water motor is fixed above the framing, and drives the centrifugal basket which is below it through an elastic coupling, the basket being fixed at the lower end of a vertical spindle which has only one bearing. The water motor, which is of the Pelton Wheel type, rotates on a ball bearing around a fixed spindle. The body of the motor (Fig. 69) is carried upwards and is turned over the casing with a double flange, upon which the buckets are mounted. The flanges prevent the water spray from getting over the top; the spent water is thus compelled to flow through the return water-pipe, back to the water tank which supplies the pump for driving the machine.

To the bottom of the water motor boss there is bolted a driving flange, upon the upper side of which there are mounted the governor balls in an oil-tight cavity, partly filled with lubricating oil, below the upper ball-bearing. The governor balls are held in the off position by the governor springs. The arms are coupled by a rod passing up the hollow spindle in the centre of the motor to a lever working on a fulcrum placed on the top

of the motor case cover; a swivelling crosshead, through which passes the governor rod, is fitted at the outer short end of the lever. When the machine attains full speed, the governor spindle is moved upwards, and the governor rod is pressed downwards, when it acts on a trigger, cutting off the water from

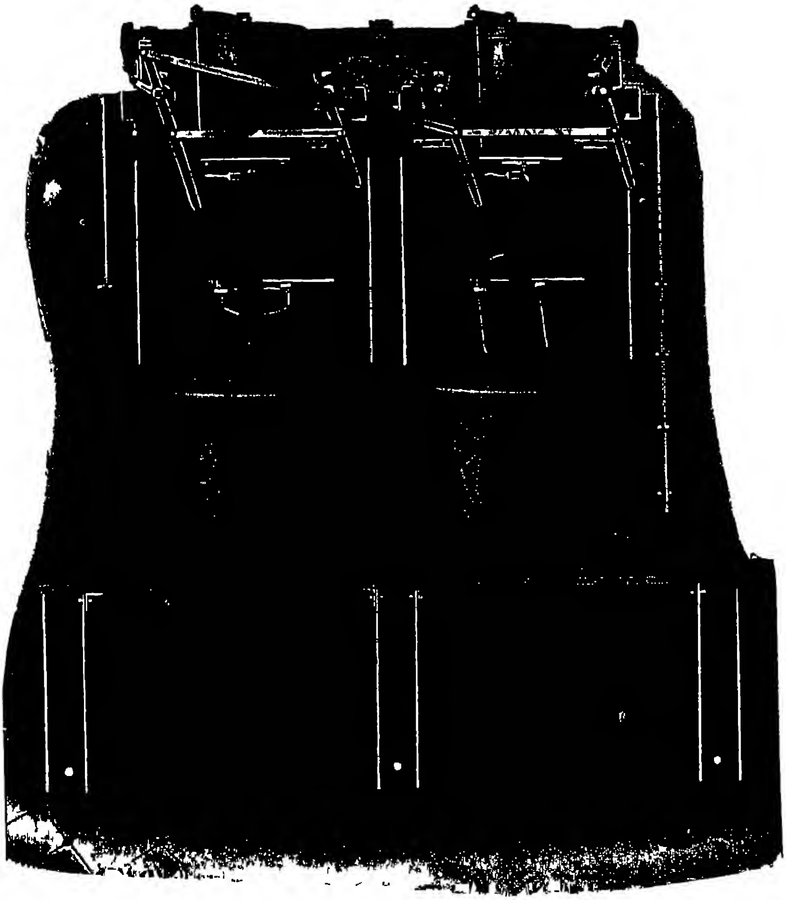


FIG. 68.—Patent Water-driven Centrifugals by Pott, Cassels & Williamson.

one of the two jets—the accelerating jet—which can be seen in the illustration, leaving the smaller maintaining jet on the opposite side in operation.

Underneath the beams is the elastic bearing carrying the

upper end of the basket spindle; into this are fitted indiarubber buffer rings, separated from each other by a loose U-shaped cast-iron ring. Both top and bottom buffers, therefore, support the weight of the centrifugal basket. This patented

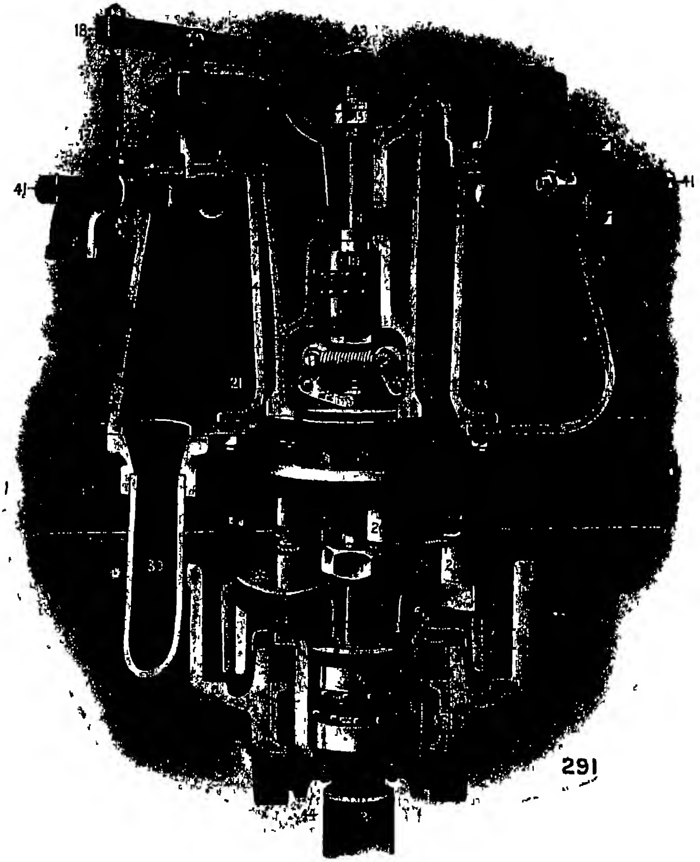


Fig. 69.—Showing Motor of Water-driven Centrifugals (Pott, Cassels & Williamson).

arrangement of buffers gives great resilience and perfect steadiness to the machine when running with a balanced or unbalanced load, and as the buffers are separated by the loose U-shaped cast-iron ring, any wear on the bottom buffer

is compensated for. The ball-bearing housing fits inside the indiarubber buffers, and contains the compound ball-bearing. To permit of the oscillation of the centrifugal spindle and basket, the water-wheel above, which does not oscillate, is con-

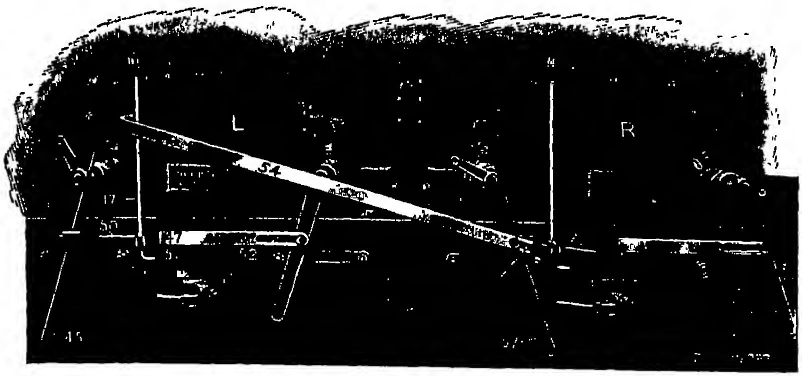


FIG. 70.—Water-driven Centrifugals. Interlocking Gear.

nected to the brake pulley on the top of the centrifugal spindle by three links, the eyes of which are slipped over the points of the driving-pins into a groove. The links thus form a strong flexible coupling, both simple and effective; the motor or the

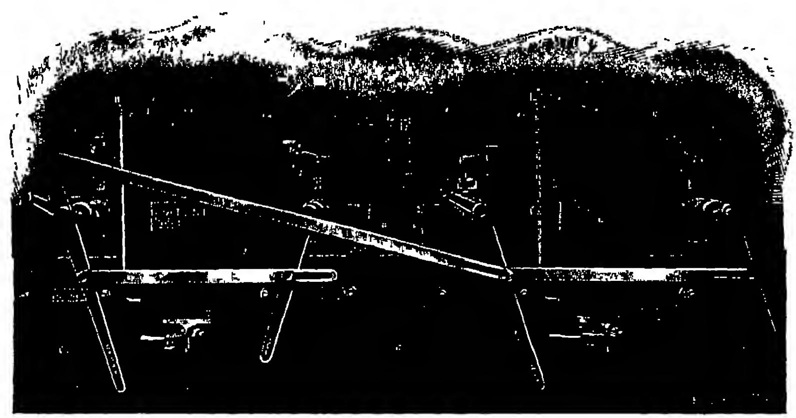


FIG 71.—Water-driven Centrifugals. Interlocking Gear.

centrifugal can be detached, when desired, by slipping off the links.

The brake band is supported by an angle iron, resting on a flange in the suspending bracket, there being thus no pos-

sibility of the brake drooping unequally. When the brake is off, there is an equal space all round between the brake band and the brake pulley.

The interlocking gear is shown in Figs. 70 and 71. This works as follows: When the interlocking lever is pushed over

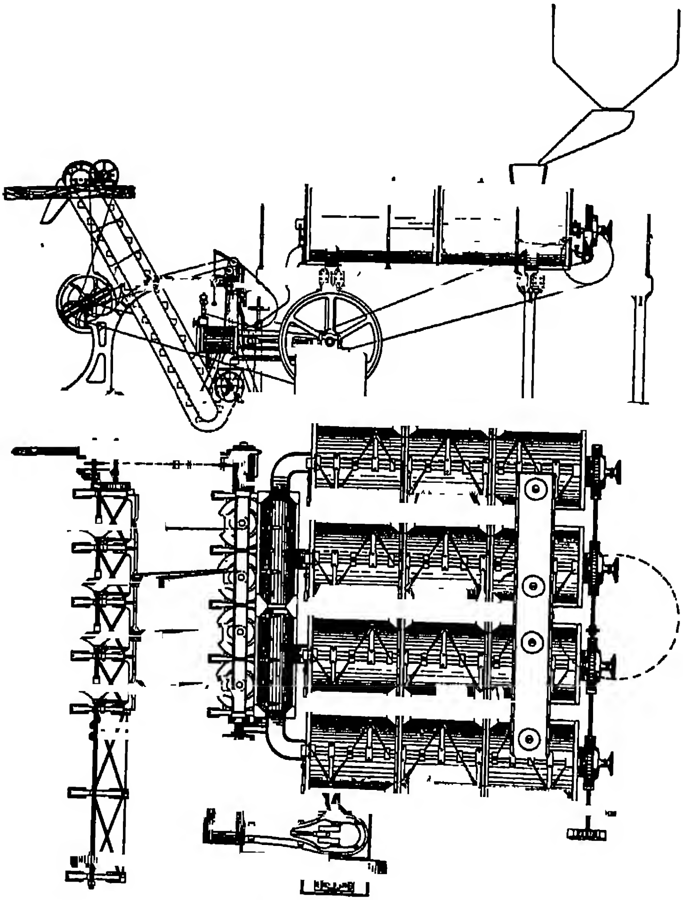


FIG. 72.—Crystallization in Motion Plant, by Pott, Cassels & Williamson.

from right to left (see Fig. 70), it opens the accelerating water valve, which is on the left-hand of the motor case, and, by means of a short connecting link, it opens at the same time the maintaining water valve, which is on the right hand of the motor case, and so causes the jets shown in the section (Fig. 70), on both sides of the water-wheel, to act on the water-wheel cups.

When the hand is removed from the accelerating lever, a spring is prevented from cutting off the accelerating water valve by the point of a small, round, horizontal trigger rod pressing against the jaw of a trigger-rod bracket, the trigger rod being pulled up into the horizontal position by the governor springs

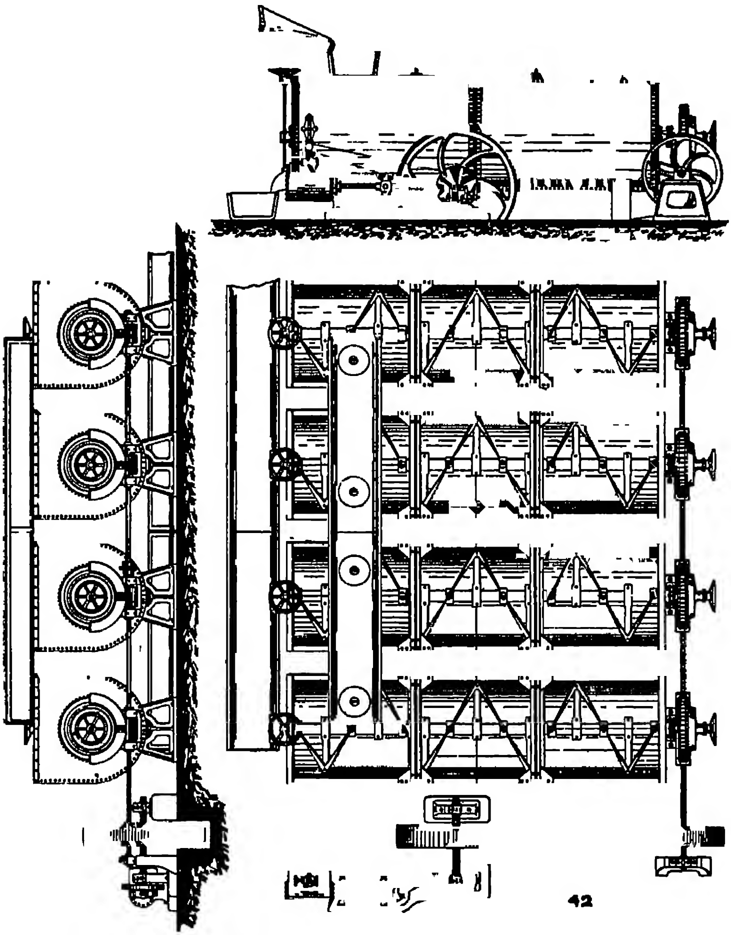


FIG 73.—Crystallization in Motion Plant, by Pott, Cassels & Williamson.

contracting when the machine was stopped the previous time. When the machine attains full speed, the governor, as above stated, pushes down the governor rod, which, in turn, pushes down the trigger rod, when the spring on the accelerating lever will shut off the accelerating water valve. The maintaining

water valve is not affected by this operation (see Fig. 71), and remains open until it is desired to stop the machine, when it is shut by hand, and the brake applied.

Fig. 72 and Fig. 73 represent a crystallization in motion plant, consisting of crystallizers, centrifugals, and mixer, engine, screw conveyer under centrifugals, and a dry sugar elevator as used in the sugar manufacture. It is illustrated here as embody-

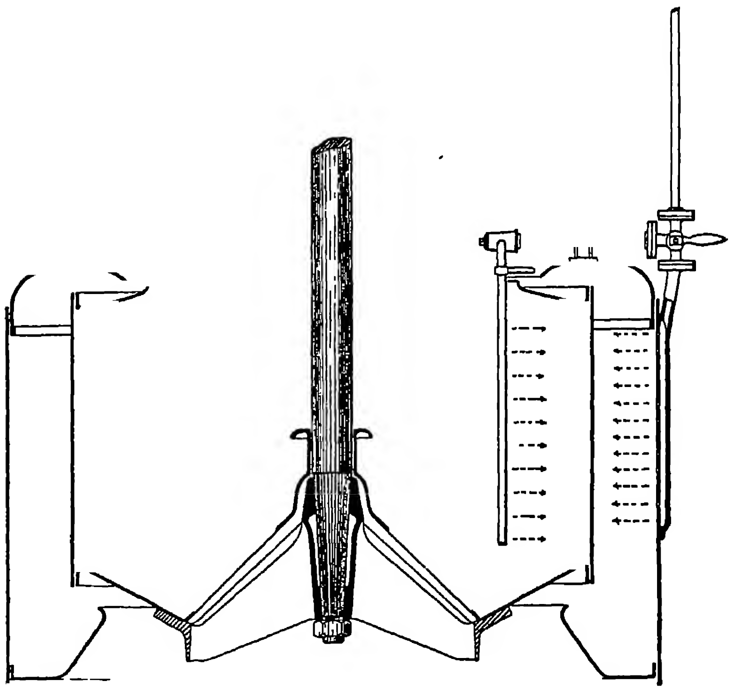


FIG. 74.—Steaming Apparatus, by Pott, Cassels & Williamson.

ing principles which are of interest. The massecuite is struck out of the vacuum pan into one of the crystallizers, each crystallizer being of such a capacity as to receive the entire "strike" of the pan The crystallizer stirring gear is then put in motion and the contents stirred continuously for a longer or shorter period of time, according to the quality of the massecuite. The time varies from twelve to twenty-four hours for first massecuite, and from one to two days for second massecuite. The contents of

the crystallizer, after being stirred for the required time, are discharged through a suitable valve into the mixer of the centri-

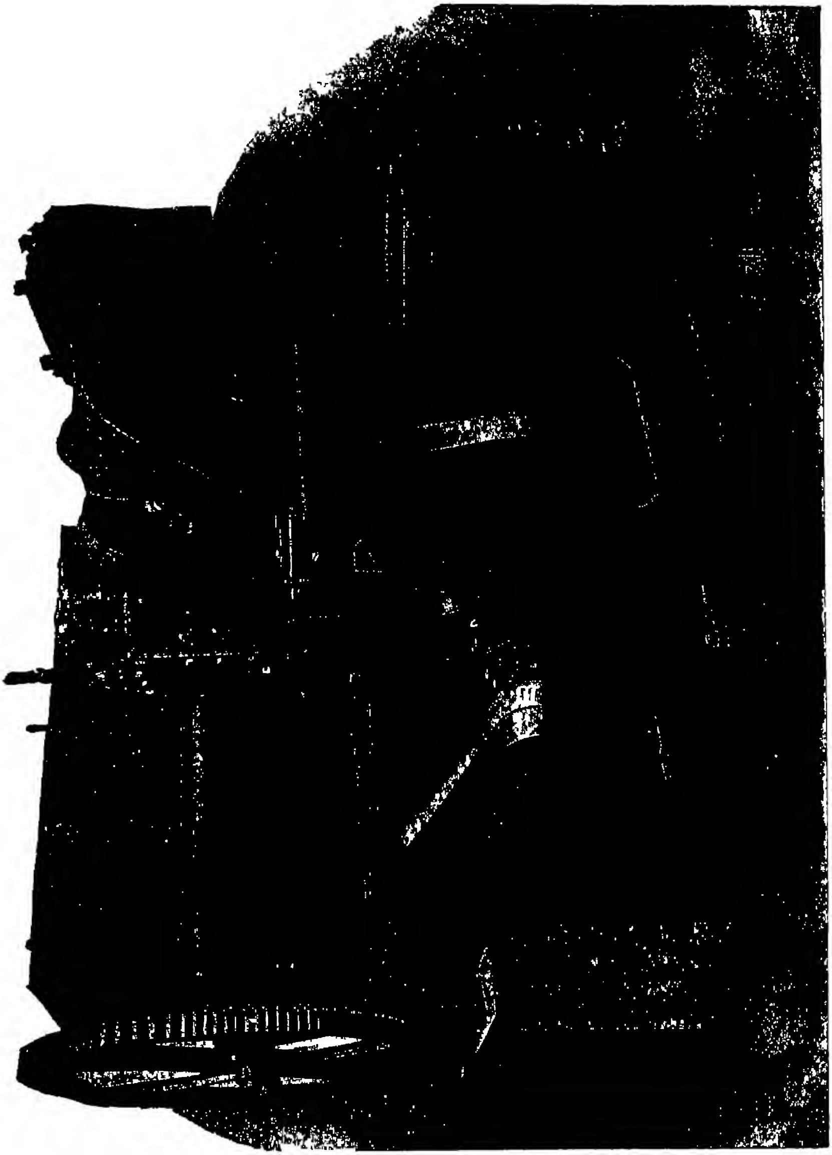


FIG. 75.—Special Centrifugal for Mixing and Drying Anthracene and Naphthalene, by Pott, Cassels & Williamson.

fugals, where the massecuite undergoes a thorough mixing. The centrifugals are fed through charging valves and the mas-

secuite is cured in the usual manner, the dry sugar being discharged through the bottom of the centrifugal into the screw conveyer and from thence to the dry sugar elevator to the sugar store. The crystallizers are fitted with friction driving gear, which enables any machine to be put in motion or stopped as desired, without interfering with the rest of the plant

Fig 74 shows an arrangement of steaming apparatus. The inside is used for cleaning or bleaching the material, and the outside steaming is for washing the inside of the monitor case. The inside steaming pipes are made so that the pipe can be lifted out of the basket by means of a swivel joint This facilitates the removal of the contents

Fig. 75 shows a special centrifugal, for mixing and drying anthracene and napthalene. The anthracene or napthalene is fed into a steam-jacketed mixer, where it is kept at the desired temperature during the process of mixing. It is then discharged into the centrifugal, spun in the usual manner, steamed, and discharged through the opening in the bottom of the centrifugal.

Vacuum Evaporator for Sulphate of Ammonia.

Fig. 76 shows an improved type of single effect vacuum evaporator for dealing with sulphate of ammonia liquors and concentrating these.

The evaporators are usually constructed of a special quality of copper for withstanding the action of the acid, and the heating surface is arranged on an improved principle to ensure the highest circulation and the best efficiency.

The illustration shows the plant fitted with a save-all of extra large size and area to prevent entrainment, and with a jet condenser exhausted by a set of belt-driven three-throw pumps. The usual practice, however, is to have a single-throw steam-driven pump, unless the plant is of very large size.

When the liquors to be dealt with are specially acid, or contain too high a percentage of chlorine, the evaporators can be constructed of steel, homogeneously lined with lead, which is found to be the most suitable in this case, and the heating surface is arranged separate from and independent of the evaporator, with connecting pipes, in one or more units, as found desirable.

Modifications of the same type of evaporator are also supplied

for soap lye, caustic potash and soda, and various other trade liquors.

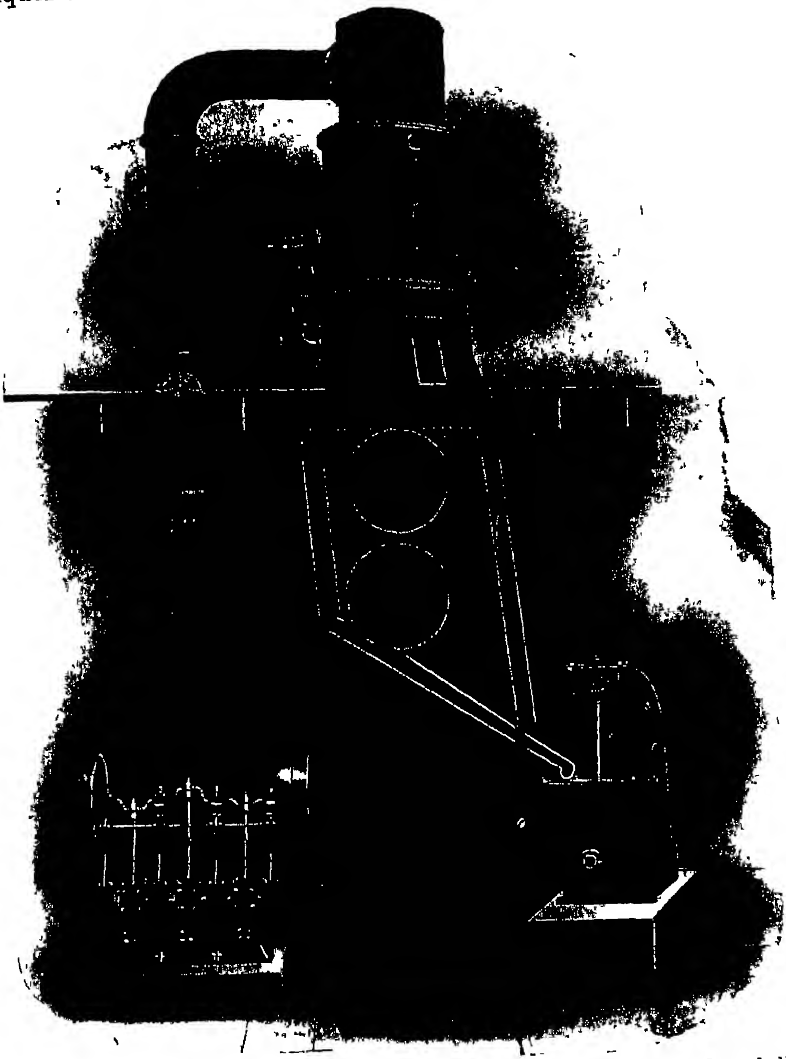


FIG. 76.—Vacuum Evaporator for Sulphate of Ammonia, by Blair, Campbell & McLean, Ltd (Govan).

VACUUM DRYING PLANT.

There are few, if any, materials requiring drying which cannot be most suitably dried in a vacuum—provided the vacuum be properly applied. Every liquid boils at a certain tempera-

ture, according to the pressure existing at the time. The greater the pressure, the higher the boiling-point. If the natural pressure of the atmosphere is removed, it is possible to remove the moisture from a body at a much lower temperature than under atmospheric conditions. The reduced boiling-point has, however, a very important bearing on the rapidity of the operation, owing to the greater speed with which the heat units are transmitted from the heating medium (steam, water, etc) to the material. Obviously, the greater the difference in temperature between these, the greater the quantity of heat transmitted in a given time

Nearly every material is adversely affected by excessive heating—either at a high temperature or by prolonged heating Consequently, the ideal drying is one of great rapidity and low temperature. This combination is, however, not to be found under atmospheric conditions—in order to dry rapidly, the boiling-point of the liquid ingredient must be approached; this means, under ordinary pressure, a high temperature and a poor product. A vacuum drying properly conducted can, however, approach the boiling-point, even reach it in some cases, and yet be merely warm

The "Scott" vacuum driers made by Messrs. George Scott and Son (London), Ltd., of Kingsway House, London, W.C., and illustrated in Figs. 77 and 78, are designed to combine in one apparatus the full advantages of a rapid drying at a low temperature.

The stationary drying apparatus or vacuum stove (Fig. 77) is the form most generally used, and consists of a solidly constructed receptacle fitted with a number of shelves, provided with a door and suitable exhausting and condensing arrangements. Such an apparatus, to be practical and useful, should be capable of turning out the product as uniform as possible This can only be obtained by securing staunchness in the steam shelves, an efficient distribution of the steam, and a free clearance and condensation of the expelled moisture. The interior of the stove should be as free from moist vapours as possible

The body of the stove is built up of heavily ribbed castings, carefully machined at every joint. The standard "Scott" stove is supplied in rectangular form, and thus saves all waste space. The back of the stove is constructed in either case in mild steel,

and carries the vacuum and steam connections. The door is specially constructed in light steel plate, with strong forged rim

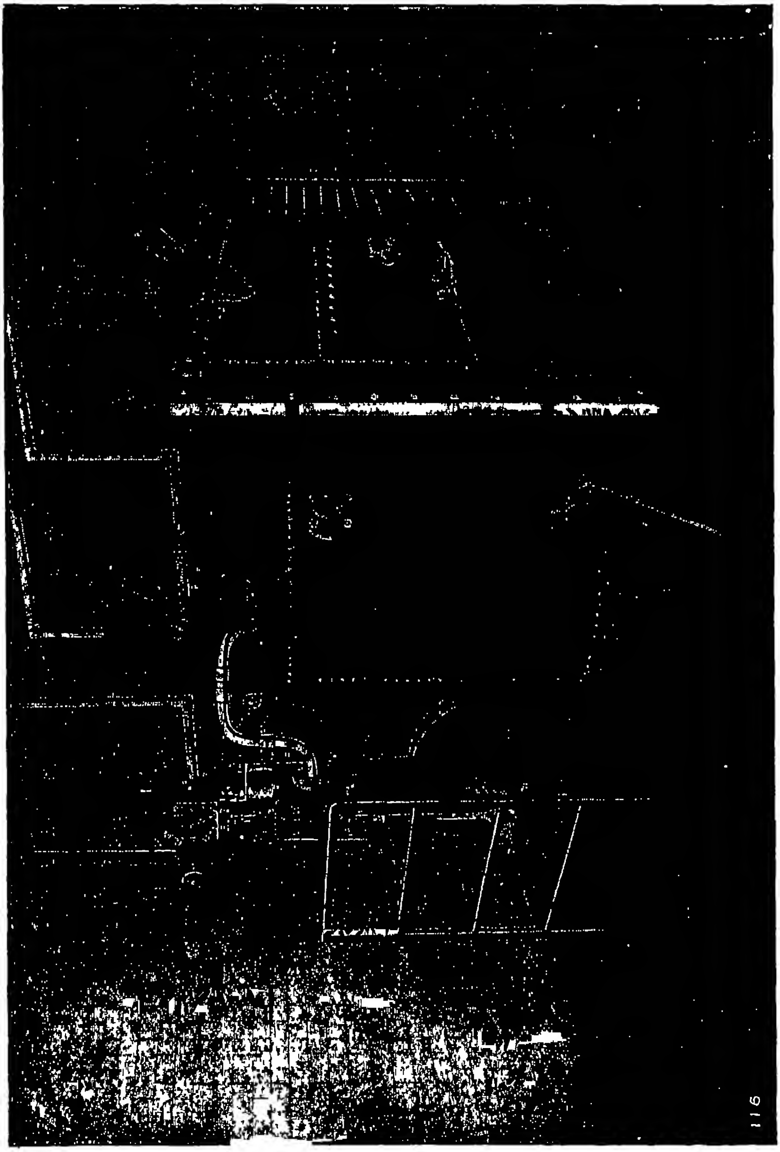


Fig. 77.—Vacuum Drying Stove.

and cross-pieces. This produces a light but strong, easily handled door. The shelves are of special grid type, made with-

out any jointing, and tested to 100-lb. pressure per square inch. The heating medium, such as steam or hot water, traverses every portion of the shelf. The exhausted vapours have free passage at the back of each shelf, and therefore pass rapidly away.

A condenser with solid drawn brass tubes is provided, with a receiver for containing the liquid driven off from the charge during drying, the latter being supplied with inspection fittings, allowing the stream of condensed liquid to be continually under

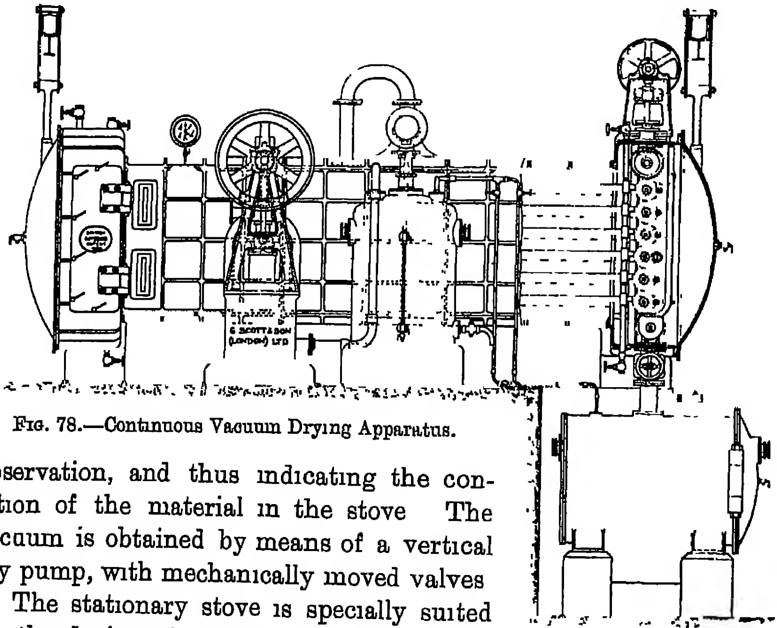


Fig. 78.—Continuous Vacuum Drying Apparatus.

observation, and thus indicating the condition of the material in the stove The vacuum is obtained by means of a vertical dry pump, with mechanically moved valves

The stationary stove is specially suited for the drying of colours, nitro-compounds, explosives, gutta-percha, casein, soap, fine chemicals, and crystals of all kinds.

The Scott Patent Continuous Dryer, shown in Fig. 78, has been designed to provide a drier combining the advantages of the vacuum stove with the absence of handling. This new drier cannot be adapted to the requirements of every substance, but is specially suitable for continuously producing a dry powder direct from the liquid without intermediate handling. The apparatus consists of a suitably constructed chamber furnished with endless metallic bands supported and put in motion by driven rollers. These bands are supplied with the liquid to be

dried by an automatic spreading device, and pass in their course over and close to steam-heated surfaces The speed of the machine is regulated so that the material is dry on reaching the farther end of the drying chamber, where revolving brushes remove the dried material and direct it into a conveyer trough, whence it finds its way into one or other of the receivers provided, which are discharged and filled alternately. The material cannot be overheated by prolonged contact with the heating surface, and in this respect the machine has a great advantage over the shelf stove. The apparatus while supplied with liquid

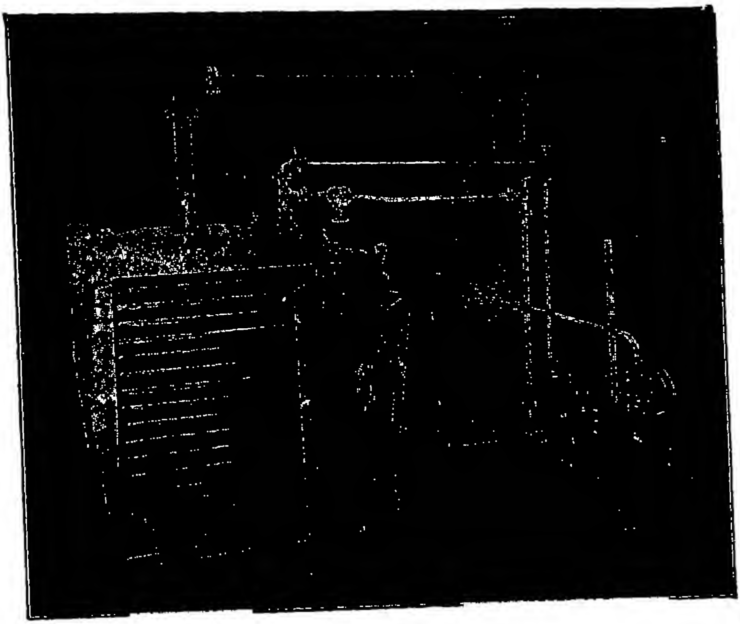


FIG. 79.—Vacuum Drying Plant.

continues to produce the one grade of material without intermission as long as may be desired.

These driers, which have been thoroughly tested in actual work, are suitable for drying such materials as glue, dye extract, tannin extracts, shellac, albumen, etc.

A type of vacuum drying plant which is in very extensive use is that made by Emil Passburg, of Berlin, and supplied in this country by Mr. James Livingstone, of 30 Great Saint Helens, London, E C., is illustrated in Fig. 79, which shows a Passburg

vacuum drying-chamber plant erected at Mr. Passburg's works prior to being packed for shipment. Many similar plants have been supplied to chemical and colour works.

The material to be dried is spread evenly upon trays, which are placed between the heating shelves in the chamber. The swinging hinged door is then closed and tightly secured, and the vacuum pump set to work. The exhaust steam from the steam cylinder of the vacuum pump is used for the heating shelves, and by the time the wet material has been warmed to about 90° F. the pump will have obtained a vacuum of 28 to 29 inches, and the moisture is removed rapidly by boiling at this low temperature. The vapour is drawn to the surface condenser, where it is condensed and collects in the base of the condenser. The average drying time for colours is from five to six hours.

Most materials in a warm, moist condition are injuriously affected by the oxygen in the air, but this action, owing to the exclusion of the air, is entirely avoided in the vacuum apparatus. The vacuum pump only requires from three-quarters to one hour to maintain the vacuum. These chambers are advantageously used for recovering spirit. The latest improvement in the construction of the chambers is that the edges of the heating shelves, which used to be riveted and had the steam inlet and outlet pipes screwed into them, are now made with welded edges, and the pipes are welded to the shelves. This improvement has done away with the lodgment of water on the bottom of the shelves and of air on the top, as the inside of the welded pipes are on the same level as the inside top and bottom of the shelves. Over a hundred Passburg chambers have been supplied to British works, and many hundreds to Continental establishments.

The shelf chamber shown is suitable for colours, chemicals, aniline and other dyes, dextrine and other gums, gambier, glue and gelatine, and all kinds of pulps and pastes, etc. Rotary dryers are also supplied for granular substances, such as starch, dextrine, saltpetre, chalk, soap-powder, artificial manures, etc.

THE SCOTT TRIPLE-EFFECT EVAPORATOR.

Fig. 80 shows a triple-effect evaporator by Messrs. George Scott & Son (London), Ltd., fitted with a final finishing pan for

completing to high strengths by the use of exhaust steam—in fact, the whole plant works throughout with exhaust steam.

The combination shown is a very complete one, as it is provided with a Torricelli or barometric self-delivery type condenser, a steam-driven displacement pump, the latter being combined with the water pump for the condenser, and a drip water pump for removing the condensed steam from the effects.

A particular feature of this apparatus (of which the makers

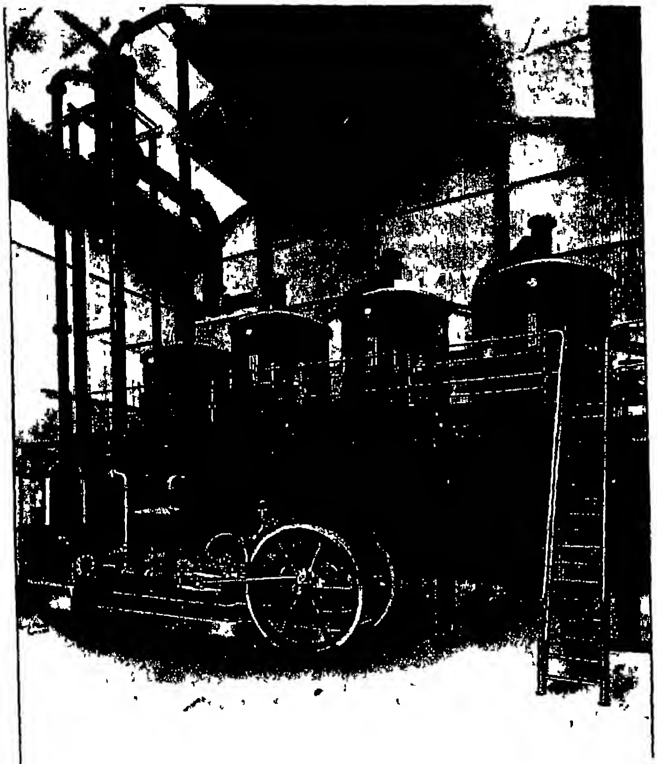


FIG 80.—Triple-effect Evaporator.

have about 4000 at work), is the patent heating system, which is in the form of a number of vertical tubes of large and small diameter, the large tubes being evenly spaced among the smaller ones, thus producing an even and very vigorous circulation. The tubes are neither particularly short tubes nor particularly long ones, and the makers have come to the conclusion, after an experience which is unapproached by any other firm, that the medium between the short and long tube is the correct thing

The tubes are long enough to produce an efficient circulation, and short enough to prevent any possibility of dry spots on the heating surface, and also short enough to allow the vapour to be freed much more readily than if a longer tube is employed. All varieties of these evaporators are made by Messrs. Scott & Son, and each is specially designed for its particular duty.

APPENDIX I.

ON THE CHEMICAL ENGINEER.

The function of the chemical engineer has now become fairly well defined, and his value more clearly appreciated than was the case even a few years ago. When a chemical manufacturer was faced with the problem of the erection of a new works, the re-modelling of an old one, or the addition of new plant to his existing equipment, it was formerly the custom for him to call in one of the contractors familiar with general chemical plant, and to rely very largely upon him for the carrying out of any constructional work that might be required. The chemical contractor had the advantage of being able to give information as to what other manufacturers were doing in connection with any particular type of plant. Frequently he would be in possession of drawings prepared by some consulting engineer, and could make use of such drawings modified to suit the particular case. He might not be an engineer in the real sense of the term. Very frequently he was nothing of the kind, and the confidence of the manufacturer was often misplaced, resulting in the expenditure of large sums of money on plant, which, in practice, proved not suitable for his requirements. Very gradually, during the last twenty years, it has been recognized by chemical manufacturers that the designing of plant for the various operations required a peculiar combination of engineering and chemical knowledge. In the first place, the materials used in the construction of the plant are not those with which the average mechanical engineer is familiar; therefore, it was obviously necessary that, in addition to some engineering skill, an extensive acquaintance with the chemical processes involved in any particular branch of manufacture was a necessary qualification in an engineer entrusted with the designing of a chemical works Such a combination of engineering and chemical know-

ledge is rarely possessed by an engineer pure and simple, and this fact has led to the evolution of a specialist who combines the two branches of scientific ability. It is often said, and that most emphatically, that in a large chemical works the most important man on the executive staff is the engineer, and in support of this argument it is asserted that the largest and most successful works are those where competent mechanical engineers are found at the head of affairs The truth of the matter is that either such engineers have secured a comparatively extensive acquaintance with the chemical operations involved, or that they have the co-operation of an equally competent staff of works chemists In many cases, as already hinted, the engineer in charge has studied the chemical side of works management, or the chief chemist has devoted much attention to the engineering details of the plant for which he is responsible In either of these cases we see the chemical engineer in the making. The engineer has absorbed sufficient chemical knowledge to convert himself into an efficient chemical engineer, or the works chemist has absorbed sufficient practical engineering to produce the same satisfactory result. Whether it be that practical engineering, plus the knowledge of chemical details, produces the desired specialist, or that technical chemistry, plus engineering knowledge, results in the same product, is quite immaterial; either process frequently produces the man who is the chemical manufacturer's best lieutenant. The secret of chemical engineering success is the combination of the two classes of technical experience. We have known typical examples of both processes of evolution, and the result has been equally satisfactory in each instance.

APPENDIX II.

THE SAW-MILL AND BOX-MAKING DEPARTMENT.

As an adjunct to a factory where the products require to be packed in boxes, a saw-mill and box-making department is necessary. Following the usual procedure with respect to other manufactured articles, of passing from the raw material to the finished product—in this case the rough timber being the raw material and the finished product the boxes—the most suitable arrangement is to have the rough timber stored close to the siding where it is unloaded. Very few firms buy the timber in the log, but content themselves with purchasing it in the St. Petersburg standard of battens or planks; or, where a cheaper supply of timber suitable for box-making is available in the shape of the rough ends of sleepers, it is common in this latter case to buy the timber by the fathom. Leading from this store, which will of course be proportioned as to size according to the output of the factory, the saw-mill is placed next to it.

A row of cross-cut benches will be the first machines to lay down, as the timber, on leaving the store, is cut up into suitable blocks, from which the boards for forming the sides and ends of the boxes will be afterwards cut. Ample room should be left between these saw-benches, so that in sawing up a plank into the various lengths there will be no risk of one saw-bench fouling another, and in this connection the room required for piling the sawn-up blocks as they are cut from the planks should be provided for.

If the saws are parallel with one another, a pit for taking the sawdust may be placed underground, running the whole length of the range of saws, and the saws placed over the pits on girders. Such an arrangement as this would lend itself most readily to the employment of mechanical means for conveying the sawdust to hoppers where it can be stored for use, or

conveyed to boilers where it may be burned as fuel. Where a very large quantity of sawdust is made, it might be advisable to consider whether it would pay to put down a wood distillation plant. Amongst several other uses for sawdust is that of the manufacture of fire-lighters, while a good deal is generally disposed of for local purposes.

Behind the range of cross-cut saws is placed a further range of circular saws, for cutting the rough blocks into suitable thicknesses to form the several parts of the boxes. If dovetailing and planing are required, these machines will be next in order, but for many purposes the boxes are sufficiently finished if made up of the timber as it leaves the saw-bench, and it only remains for the several parts to be passed on to the box-nailing machines. In our suggested plan of a saw-mill, we have only taken into consideration the production of boxes made in the rough, and therefore only requiring the saw-benches and box-nailing machines to complete the boxes ready for the store.

As adjuncts to the box-making department, a printing press may be required, or a branding department, but these can easily be added to the suggested design.

Where electricity is the motive power the counter-shaft for the saws may run at a high speed, as there would be no advantage in reducing the speed from the motor to a counter-shaft, and again increasing it to the saws, as most of these will be running at from 800 to 1000 revolutions per minute. A counter-shaft will be needed for the box-nailing machines, as these only run at something like sixty to eighty revolutions per minute.

In many factories where the products are packed in boxes, and even where a sawmill is installed, it is customary to buy the component parts of the boxes all ready for putting together. These parts can be purchased either in the rough, or planed or dove-tailed, and stamped with name or brand, and in this case it is customary to fix a piecework price for the carpenters to put the boxes together, prices naturally varying according to the amount of labour required, as to whether the box is put together with screws, nailed, or the lids strengthened with battens, or any additions of this nature. In some cases boxes are made with rope handles, in which case the fixing of these is an extra. Again, the boxes are sometimes required to be watertight, when

they are passed on from the sawmill to the plumber to lead-line, and this operation in some works becomes a large department.

It will of course be necessary to keep down as far as possible the stock of ready-made boxes, as the space occupied by a large stock is very great, and in most cases the supply is so well regulated to the demand as not to cause any great storage to be necessary.

The low cost at which foreign boxes, all ready for making up, can be procured, should be carefully taken into consideration where only a limited supply is required before putting down a mill for their production, unless sizes are apt to vary frequently.

Boxes used in the explosives trade are generally well finished, in some cases planed both sides, but in any case planed on one side. They are usually dove-tailed and put together with brass screws. The commoner boxes are sometimes nailed together with copper nails, but no iron nails or screws are permissible

APPENDIX III.

THE ALKALI, ETC., WORKS REGULATION ACT.

PART I.—ALKALI WORKS AND ALKALI WASTE.

1.—(1) Every alkali work shall be carried on in such manner as to secure the condensation, to the satisfaction of the chief inspector, of the muriatic gas evolved in such work, to the extent of 95 per centum, and to such an extent that in each cubic foot of air, smoke, or chimney gases, escaping from the works into the atmosphere, there is not contained more than one-fifth part of a grain of muriatic acid

(2) The owner of any alkali work which is carried on in contravention of this section shall be liable to a fine not exceeding, in the case of the first offence, £50, and in the case of every subsequent offence £100.

2.—(1) In addition to the condensation of muriatic acid gas as aforesaid, the owner of every alkali work shall use the best practicable means for preventing the escape of noxious or offensive gases by the exit flue of any apparatus used in any process carried on in the work, and for preventing the discharge of such gases into the atmosphere, whether directly or by a chimney or other outlet, and for rendering such gases where discharged harmless and inoffensive, subject to the qualification that, on the basis of the amount of the acid gas per cubic foot, no objection shall be taken under this section by an inspector to any muriatic acid gas in the air, smoke, or gases discharged into the atmosphere by a chimney or other outlet where the amount of such acid gas in each cubic foot of air, smoke, or gases so discharged does not exceed the amount limited by the last preceding section.

(2) If the owner of any alkali work fails, in the opinion of the court having cognisance of the matter, to use such means, he shall be liable to a fine not exceeding, in the case of the first

offence, £20, and in the case of every subsequent offence, £50, with a further sum not exceeding £5 for every day during which any subsequent offence has continued.

3.—(1) Every work of whatever description in which any liquid containing either acid or any substance capable of liberating sulphuretted hydrogen from alkali waste or drainage therefrom is produced or used shall be carried on in such manner that the liquid shall not come in contact with alkali waste, or with drainage therefrom, so as to cause a nuisance.

(2) The owner of any work which is carried on in contravention of this section shall be liable to a fine not exceeding, in the case of the first offence, £50, and in the case of every subsequent offence, £100, with a further sum not exceeding £5 for every day during which the offence has continued.

(3) On the request of the owner of any such work as is mentioned in this section the sanitary authority of the district in which such work is situate shall, at the expense of such owner provide and maintain a drain or channel for carrying off such liquid into the sea or into any river or watercourse into which the liquid can be carried without contravention of the Rivers Pollution Act, 1876, as amended by any subsequent enactment; and the sanitary authority shall for the purpose of providing any such drain or channel have the like powers as they have for providing sewers within or without their district, under the Public Health Act.

(4) Compensation shall be made to any person for any damage sustained by him by reason of the exercise by a sanitary authority of the powers conferred by this section, and such compensation shall be deemed part of the expenses to be paid by the owner making the request to the sanitary authority under this section.

4.—(1) Alkali waste shall not be deposited or discharged without the best practical means being used for effectually preventing any nuisance arising therefrom.

(2) Any person who causes or knowingly permits any alkali waste to be deposited or discharged in contravention of this section shall be liable to a fine not exceeding, in the case of the first offence, £20, and in the case of every subsequent offence, £50, with a further sum not exceeding £5 for every day during which any such subsequent offence has continued.

5.—Where alkali waste has been deposited or discharged,

either before or after the commencement of this Act, and complaint is made to the chief inspector that a nuisance is occasioned thereby, the chief inspector, if satisfied of the existence of the nuisance, and that it is within the power of the owner or occupier of the land to abate it, shall serve a notice on such owner or occupier requiring him to abate the nuisance; and if such owner or occupier fails to use the best practicable and reasonably available means for the abatement thereof he shall be liable to a fine not exceeding £20, and if he does not proceed to use such means within such time as may be limited by the court inflicting such fine he shall be liable to a further penalty not exceeding £5 for every day after the expiration of the time so limited during which such failure continues.

PART II.—SULPHURIC ACID, MURIATIC ACID, AND OTHER SPECIFIED WORKS.

6.—(1) Every sulphuric acid work, as defined in paragraph (1) of the First Schedule to this Act shall be carried on in such manner as to secure the condensation, to the satisfaction of the chief inspector, of the acid gases of sulphur or of sulphur and nitrogen which are evolved in the process of the manufacture of sulphuric acid in that work, to such an extent that the total acidity of those gases in each cubic foot of residual gases after completion of the process, and before admixture with air, smoke, or other gases, does not exceed what is equivalent to four grains of sulphuric anhydride

(2) Every muriatic acid work, as defined in paragraph (8) of the First Schedule to this Act, shall be carried on in such manner as to secure the condensation to the satisfaction of the chief inspector of the muriatic acid gas evolved in such work, to such extent that in each cubic foot of air, smoke, or chimney gases escaping from the work into the atmosphere, there is not contained more than one-fifth part of a grain of muriatic acid.

(3) The owner of any sulphuric acid work, or of any muriatic acid work which is carried on in contravention of this section, shall be liable to a fine not exceeding, in the case of the first offence, £50, and, in the case of every subsequent offence, £100.

7.—(1) The owner of any work specified in the First Schedule to this Act (hereinafter referred to as a scheduled work) shall use the best practicable means for preventing the escape of

noxious or offensive gases by the exit flue of any apparatus used in any process carried on in the work, and for preventing the discharge of such gases into the atmosphere, whether directly or by a chimney or other outlet, and for rendering such gases where discharged harmless and inoffensive, subject to the qualification, that on the basis of the amount of acid gas per cubic foot, no objection shall be taken under this section by an inspector:—

(*a*) To any muriatic acid gas in the air, smoke, or gases discharged into the atmosphere by a chimney or other outlet, where the amount of such acid gas in each cubic foot of air, smoke, or gases so discharged does not exceed the amount limited by the last preceding section.

(*b*) To any acid gases in the air, smoke, or gases discharged into the atmosphere by a chimney or other outlet receiving the residual gases from any process for the concentration or distillation of sulphuric acid, where the total acidity of such acid gases (including those from the combustion of coal) in each cubic foot of air, smoke, or gases so discharged does not exceed what is equivalent to one grain and a half of sulphuric anhydride.

(2) If the owner of any such work fails, in the opinion of the court having cognizance of the matter, to use such means, he shall be liable to a fine not exceeding, in the case of the first offence, £20, and, in the case of every subsequent offence, £50, with a further sum not exceeding £5 for every day during which any such subsequent offence has continued

8.—(1) An inspector may inquire whether, in any works in which aluminous deposits are treated for the purpose of making cement, hereinafter called cement works, means can be adopted at a reasonable expense for preventing the discharge from the furnaces or chimneys of such works into the atmosphere of any noxious or offensive gas evolved in such works, or for rendering such gas where discharged harmless or inoffensive.

(2) Where it appears to the Local Government Board that such means can be adopted at a reasonable expense, the Board may by order require the owners of such works to adopt the best practicable means for the purpose, and may by the order limit the amount or proportion, in the case of cement works of any noxious or offensive gas, which is to be permitted to escape

from such works into the chimney or into the atmosphere, and may also by the order extend to such works such provisions of this Act relating to scheduled works as they think fit.

(3) An order made under this section shall be provisional only, and shall not be of any validity until confirmed by Parliament, but when so confirmed shall have full effect, with such modification as may be made therein by Parliament; and the expression "this Act" when used in this Act shall be deemed to include an order so confirmed, so far as is consistent with the tenor of that order.

(4) The Board shall take such steps as they may think fit for giving notice to persons interested of the provisions of any order made by them under this section before any bill for confirming the same is introduced into Parliament.

(5) An order made under this section may impose fines for a breach of its provisions of like amount as any fines imposed by this Act for offences against this Act.

(6) An order made under this section may be repealed, altered, or amended by any subsequent order made under this section, and confirmed by Parliament

PART III.—(i) REGISTRATION OF WORKS

9.—(1) An alkali work, a scheduled work, or cement work, shall not be carried on unless it is certified to be registered

(2) The work shall be registered in a register containing the prescribed particulars, and the register shall be conducted and the certificates issued in the prescribed form.

(3) A certificate of registration, if issued at a time when a previous certificate is in force, shall be in force for one year after the time when that certificate ceases to be in force, and if issued at a time when no previous certificate is in force shall be in force until the following first day of April.

(4) An application for a certificate of registration of a work may, in the case of the first registration of that work, be made at any time, and an application for any subsequent certificate shall be made in the month of January or February.

(5) A certificate of registration shall be issued on application being made in the prescribed manner by the owner of the work, if the conditions of registration are complied with, and one of the conditions, in the case of the first registration of an alkali

or scheduled work, or the registration of such a work if the work has been closed for a period of twelve months previously, shall be that the work is at the time of registration furnished with such appliances as appear to the chief inspector or, on appeal, to the Local Government Board to be necessary in order to enable the work to be carried on in accordance with such of the requirements of this Act as apply to the work.

Provided that the Local Government Board may dispense with the last-mentioned condition in the case of works erected before the commencement of this Act which were not before the commencement of this Act required to be registered.

(6) There shall be charged upon every such certificate a stamp duty of £5 in the case of an alkali work, and of £3 in the case of any other work; and the Commissioners of Inland Revenue shall issue stamped forms of certificate for the purpose.

(7) Written notice of any change which occurs in the ownership of a work, or in the other particulars stated in the register shall within one month after such change be sent by the owner to the Local Government Board, and the register and the certificate shall be altered accordingly in the prescribed manner without charge and without the issue of a new certificate. If such notice is not sent as so required, the work shall not be deemed to be certified to be registered.

(8) The owner of a work which has been carried on in contravention of this section shall be liable to a fine not exceeding £50.

(ii) INSPECTION.

(10).—1 The Local Government Board shall, with the approval of the Treasury as to numbers and salaries or remuneration, appoint such inspectors (under whatever title they may fix) as the Board think necessary for the execution of this Act, and may assign them their duties and award them their salaries or remuneration, and shall constitute a chief inspector, and may regulate the cases and manner in which the inspectors are to execute and perform the powers and duties of inspectors under this Act, and may remove such inspectors.

(2) Notice of the appointment of every such inspector shall be published in the "London Gazette," and a copy of the "Gazette" shall be evidence of the appointment.

(3) The salaries or remuneration of the inspectors, and such

expenses of the execution of this Act as the Treasury may sanction, shall be paid out of moneys provided by Parliament.

(4) A person holding the office of chief inspector or inspector shall not be employed in any other work except with the sanction of the Local Government Board.

11.—A person who—

(*a*) acts or practises as a land agent; or

(*b*) is engaged or interested directly or indirectly in any work to which this Act applies, or in any patent for any process or apparatus carried on or used in any such work, or in any process or apparatus connected with the condensation of acid gases, or with the treatment of alkali waste, or with preventing the discharge into the atmosphere or rendering harmless or inoffensive any noxious or offensive gas, or otherwise with any of the matters dealt with by this Act; or

(*c*) is employed in or about or in connection with any work to which this Act applies, or in any other chemical work for gain,

shall be disqualified to act as an inspector under this Act.

12.—(1) For the purpose of the execution of this Act, an inspector may at all reasonable times by day and night, without giving previous notice, but so as not to interrupt the process of the manufacture,

(*a*) enter and inspect any work to which, in the opinion of the Local Government Board, any of the provisions of this Act applies; and

(*b*) examine any process causing the evolution of any noxious or offensive gas, and any apparatus for condensing any such gas, or otherwise preventing the discharge thereof into the atmosphere, or for rendering any such gas harmless or inoffensive when discharged; and

(*c*) ascertain the quantity of gas discharged into the atmosphere, condensed or otherwise dealt with; and

(*d*) enter and inspect any place where alkali waste is treated or deposited, or any liquid containing either acid or any other substance capable of liberating sulphuretted hydrogen from alkali waste or drainage

therefrom is likely to come into contact with alkali waste or drainage therefrom; and

(e) apply any such tests and make any such experiments, and generally make any such inquiries, as seem to him to be necessary or proper for the execution of his duties under this Act.

(2) The owner of any such work shall, on the demand of the chief inspector, furnish him within a reasonable time with a sketch plan, to be kept secret, of those parts of such work in which any process causing the evolution of any noxious or offensive gas or any process for the condensation of such gas, or for preventing the discharge thereof into the atmosphere, or for rendering any such gas harmless or inoffensive when discharged is carried on.

(3) The owner of every such work and his agents shall render to every inspector all necessary facilities for entry, inspection, examination and testing in pursuance of this Act.

(4) Every owner of a work in which such facilities are not afforded to an inspector as required by this Act, or in which an inspector is obstructed in the execution of his duty under this Act, and every person wilfully obstructing an inspector in the execution of his duty under this Act, shall be liable on conviction under the Summary Jurisdiction Acts to a fine not exceeding £10.

13.—The chief inspector shall, on or before the 1st day of March in every year, make a report in writing to the Local Government Board of the proceedings of himself and of the other inspectors under this Act, and a copy of such report shall be laid before both Houses of Parliament.

14.—(1) If any sanitary authority apply to the central authority for an additional inspector under this Act, and undertake to pay a proportion of his salary or remuneration, not being less than one-half, the Local Government Board may (if they see fit), with the sanction of the Treasury, appoint an additional inspector under this Act, to reside within a convenient distance of the works he is required to inspect; and such inspector shall have the same powers and be subject to the same power of removal and the same regulations and liabilities as other inspectors under this Act.

(2) The proportion of salary or remuneration aforesaid shall

be paid at prescribed times into the Exchequer, and shall be a debt due from the sanitary authority to the Crown.

(iii) SPECIAL RULES.

15.—(1) The owner of an alkali work, or of a scheduled work, may, with the sanction of the central authority, make special rules for the guidance of his workmen who are employed in or in connection with any process causing the evolution of any noxious or offensive gas, or in or in connection with the condensation or other treatment of that gas, and may annex fines to any violation of such rules, so that the fine for any offence do not exceed £2.

(2) A printed copy of the special rules in force under this section in any work shall be given by the owner of that work to every person working or employed in or about that work who is affected thereby.

(3) Any fine incurred under this Act in respect of an offence against a special rule may be recovered in accordance with the Summary Jurisdiction Acts.

(iv) PROCEDURE.

16.—In calculating the proportion of acid to a cubic foot of air, smoke, or gases, for the purpose of this Act, such air, smoke, or gases shall be calculated at the temperature of 60 degrees of Fahrenheit's thermometer, and at a barometric pressure of 30 inches.

17.—The following regulations shall have effect with respect to the recovery of fines for offences under this Act other than fines recoverable summarily.

(1) Every such fine shall be recovered by action in the county court having jurisdiction in the district in which the offence is alleged to have been committed.

(2) The action shall not be brought without the sanction of the central authority, nor by any person other than the chief inspector or such other inspector as the Local Government Board may in any particular case direct, nor, except as respects a fine for the contravention of the provisions of this Act as to the registration of works, after the expiration of three months from the commission of the offence, and for the purposes of such action the fine shall be deemed to be a debt due to such inspector.

(3) The plaintiff in any action for a fine under this Act shall be presumed to be an inspector authorized under this Act to bring the action, until the contrary is proved by the defendant.

(4) The court may on the application of either party, appoint a person to take down in writing the evidence of the witnesses, and may award to that person such remuneration as the court thinks just; and the amount so awarded shall be deemed to be costs in the action.

(5) If either party in any action under this Act, feels aggrieved by the decision or the direction of the court in point of law, or on the merits or in respect of the admission or rejection of any evidence, he may appeal to the High Court.

(6) Subject to the provisions of this section, all the enactments, rules and orders relating to proceedings in actions in county courts, and to enforcing judgments in county courts, and to appeals shall apply as if the action related to a matter within the ordinary jurisdiction of the court.

18.—(1) In any proceeding under this Act in relation to a fine for an offence other than an offence against a special rule:—

(*a*) It shall be sufficient to allege that any work is a work to which this Act applies, without more; and

(*b*) It shall be sufficient to state the name of the registered or ostensible owner of the work, or the title of the firm by which the employer of persons in such work is generally known.

(2) A person shall not be subject to a fine under this Act for more than one offence in respect of the same work or place in respect of any one day.

(3) Not less than twenty-one days before the hearing of any proceeding against an owner to recover a fine under this Act for failing to secure the condensation of any gas to the satisfaction of the chief inspector, or for failing to use the best practicable means as required by this Act, an inspector shall serve on the owner proceeded against a notice in writing stating, as the case requires, either the facts on which such chief inspector founds his opinion, or the means which such owner has failed to use, and the means which, in the chief inspector's opinion would suffice, and shall produce a copy of such notice before the court having cognisance of the matter.

(4) A person shall not be liable under this Act to an increased

fine in respect of a second offence, or in respect of a third or any subsequent offence, unless a fine has been recovered within the preceding twelve months against such person for the first offence or the second or other offence, as the case may be.

19.—All fines recovered under this Act, other than fines recovered summarily, shall be paid into the Exchequer.

20.—The owner of a work in which an offence under this Act other than an offence against a special rule has been proved to have been committed shall in every case be deemed to have committed the offence, and shall be liable to pay the fine, unless he proves to the satisfaction of the court before which any proceeding is instituted to recover such fine, that he has used due diligence to comply with and to enforce the execution of this Act, and that the offence in question was committed, without his knowledge, consent, or connivance, by some agent, servant, or workman, whom he shall name as the actual offender; in which case such agent, servant, or workman shall be liable to pay the fine, and proceedings may be taken against him for the recovery thereof and of the costs of all proceedings which may be taken either against himself or against the owner under the Act.

Provided that it shall be lawful for the inspector to proceed against the person whom he believes to be the actual offender, without first proceeding against the owner, in any case where the inspector is satisfied that the owner has used all due diligence to comply with and to enforce the provisions of this Act, and that the offence has been committed by that person without the knowledge, consent, or connivance of the owner.

21.—Any notice, summons, or other document required or authorized for the purposes of this Act to be delivered to or served on or sent to the owner of any work, may be served by post or by delivering the same to the owner, or at his residence or works; and the document shall be deemed to be properly addressed if addressed to the registered address of an owner, or when required to be served on or sent to the owner of any works, if addressed to the owner of the works at the works, with the addition of the proper postal address, but without naming the person who is owner

22.—(1) Where complaint is made to the central authority by any sanitary authority, or information is given by any of

their officers or any ten inhabitants of their district, that any work to which this Act applies is carried on (either within or without the district) in contravention of this Act or that any alkali waste is deposited or discharged (either within or without the district) in contravention of this Act, and that a nuisance is occasioned thereby to any of the inhabitants of their district, the central authority shall make such inquiry into the matters complained of, and after the inquiry may direct such proceedings to be taken by an inspector as they think fit and just.

(2) The sanitary authority complaining shall if so required by the central authority, pay the expense of such inquiry.

23.—(1) Where a nuisance arising from a discharge of any noxious or offensive gas or gases is wholly or partially caused by the acts or defaults of the owners of several works to which any of the provisions of this Act applies, any person injured by such nuisance may proceed against any one or more of such owners, and may recover damages from each owner made a defendant in proportion to the extent of the contribution of that defendant to the nuisance, notwithstanding that the Act or default of that defendant would not separately have caused a nuisance.

(2) This section shall not authorize the recovery of damages from any defendant who can produce a certificate from the chief inspector that in the works of that defendant the requirements of this Act have been complied with when the nuisance arose

(v) Miscellaneous.

24.—Any expenses incurred by a sanitary authority under this Act shall be defrayed as general expenses incurred by the authority in the execution of the Public Health Act.

25.—In determining any matter which under this Act is to be determined by the chief inspector, the chief inspector may found his opinion on facts disclosed by his own examination, or by an examination by any other inspector.

26—(1) For a period of three years after the commencement of this Act, paragraph (*b*) of section 7 of this Act shall apply where the process for the concentration of sulphuric acid is that known as the overheat pan process, as if in that paragraph two grains of sulphuric anhydride were substituted for one grain and a half of sulphuric anhydride.

(2) For the purposes of this section "the overheat pan process" means the process in which the concentration of sulphuric acid is effected by the passage of the heated gases resulting from the combustion of fuel over the surface of the acid.

27.—(1) In this Act, unless the context otherwise requires, the expression "alkali work" means every work for—

(a) the manufacture of sulphate of soda or sulphate of potash; or

(b) the treatment of copper ores by common salt or other chlorides whereby any sulphate is formed, or in which muriatic acid gas is evolved. The expression "noxious or offensive gas" includes the following gases and fumes: muriatic acid; sulphuric acid; sulphurous acid, except that arising solely from the combustion of coal; nitric acid and acid-forming oxides of nitrogen; sulphuretted hydrogen; chlorine and its acid compounds; fluorine compounds; cyanogen compounds; bisulphide of carbon; chloride of sulphur; fumes from cement works; fumes containing lead, copper, antimony, arsenic, zinc, or their compounds; fumes from tar works.

The expression "owner" includes any lessee, occupier, or any other person carrying on any work to which this Act applies.

The expression "best practicable means," where used with respect to the prevention of the escape of noxious and offensive gases, has reference not only to the provision and the efficient maintenance of appliances adequate for preventing such escape, but also to the manner in which such appliances are used and to the proper supervision, by the owner, of any operation in which such gases are evolved.

The expression "prescribed" means prescribed by the Local Government Board.

The expression "Local Government Board" means the Local Government Board established by the Local Government Board Act, 1871.

The expression "central authority" means as regards England the Local Government Board, as regards Ireland the Local Government Board for Ireland, and as regards Scotland the Secretary for Scotland.

The expression "sanitary authority" means any local authority entrusted with the execution of the Public Health Act.

The expression "the Public Health Act" means, as regards England, the Public Health Act, 1875, or, in the case of London, the Public Health (London) Act, 1891; and, as regards Scotland, the Public Health (Scotland) Act, 1897; and, as regards Ireland, the Public Health (Ireland) Act, 1878, and includes any enactment amending those Acts.

(2) Nothing in this Act shall be construed as exempting any work from any provisions of this Act applicable to the work as being a work of a certain class or description by reason only that the work is subject to other provisions of this Act as being a work of some other class or description.

28.—In the application of this Act to Scotland:—

(*a*) References to the Secretary for Scotland shall be substituted for references to the Local Government Board, and references to the "Edinburgh Gazette" shall be substituted for references to the "London Gazette";

(*b*) the court of the sheriff or the sheriff substitute of the county in which the offence is committed shall be the county court, and may award costs to either party, and may sentence the offender to imprisonment for any period not exceeding six months, unless the fine and costs be previously paid; and any decision or sentence of such sheriff or sheriff-substitute shall be subject to review and appeal according to law.

29.—Nothing in this Act shall legalize any act or default that would, but for this Act, be deemed to be a nuisance, or otherwise be contrary to law, or deprive any person of any remedy by action, indictment, or otherwise, to which he would have been entitled if this Act had not passed.

30.—The Acts specified in the Second Schedule to this Act are hereby repealed to the extent mentioned in the third column of the Schedule.

Provided that:—

(*a*) Nothing in this Act shall affect any certificate, special rule, or notice issued, made, or served before the commencement of this Act, in pursuance of any

enactment so repealed, but every such certificate, special rule, and notice shall continue in force as if issued, made, or served in pursuance of this Act; and

(*b*) Nothing in this Act shall affect the tenure of office of any inspector appointed under any enactment so repealed, but every such inspector shall hold office as if appointed under this Act; and

(*c*) Nothing in this Act shall affect any liability of a sanitary authority incurred under any enactment so repealed to pay any proportion of the salary or remuneration of an additional inspector.

First Schedule.—List of Works.

(1) Sulphuric acid works, that is to say, works in which the manufacture of sulphuric acid is carried on by the lead-chamber process, namely, the process by which sulphurous acid is converted into sulphuric acid by the agency of oxides of nitrogen and by the use of a lead-chamber.

(2) Sulphuric acid (Class II) works, that is to say, works in which the manufacture of sulphuric acid is carried on by any process other than the lead-chamber process, and works for the concentration or distillation of sulphuric acid.

(3) Chemical manure works, that is to say, works in which the manufacture of chemical manure is carried on and works in which any mineral phosphate is subjected to treatment involving chemical change through the application or use of any acid.

(4) Gas-liquor works, that is to say, works (not being sulphate of ammonia works or muriate of ammonia works) in which sulphuretted hydrogen or any other noxious or offensive gas is evolved by the use of ammonical liquor in any manufacturing process, and works in which any such liquor is desulphurized by the application of heat in any process connected with the purification of gas.

(5) Nitric acid works, that is to say, works in which the manufacture of nitric acid is carried on and works in which nitric acid is recovered from oxides of nitrogen

(6) Sulphate of ammonia works and muriate of ammonia works, that is to say, works in which the manufacture of sulphate of ammonia or muriate of ammonia is carried on.

(7) Chlorine works, that is to say, works in which chlorine is made or used in any manufacturing process.

(8) Muriatic acid works, that is to say :—

(a) Muriatic acid works, or works (not being alkali works as defined in this Act) where muriatic acid gas is evolved either during the preparation of liquid muriatic acid or for use in any manufacturing process;

(b) tin plate flux works, that is to say, works in which any residue or flux from tin plate works is calcined for the utilization of such residue or flux, and in which muriatic acid gas is evolved; and

(c) salt works, that is to say, works (not being works in which salt is produced by refining rock salt, otherwise than by the dissolution of rock salt at the place of deposit), in which the extraction of salt from brine is carried on, and in which muriatic acid gas is evolved.

(9) Sulphide works, that is to say, works in which sulphuretted hydrogen is evolved by the decomposition of metallic sulphides, or in which sulphuretted hydrogen is used in the production of such sulphides.

(10) Alkali waste works, that is to say, works in which alkali waste or the drainage therefrom is subjected to any chemical process for the recovery of sulphur or for the utilization of any constituent of such waste or drainage.

(11) Venetian-red works, that is to say, works for the manufacture of Venetian red, crocus, or polishing powder, by heating sulphate or some other salt of iron.

(12) Lead deposit works, that is to say, works in which the sulphate of lead deposit from sulphuric acid chambers is dried or smelted.

(13) Arsenic works, that is to say, works for the preparation of arsenious acid, or where nitric acid or a nitrate is used in the manufacture of an arsenic acid or an arseniate.

(14) Nitrate and chloride of iron works, that is to say, works in which nitric acid or a nitrate is used in the manufacture of nitrate or chloride of iron.

(15) Bisulphide of carbon works, that is to say, works for the manufacture of bisulphide of carbon

(16) Sulphocyanide works, that is to say, works in which the

manufacture of any sulphocyanide is carried on by the reaction of bisulphide of carbon upon ammonia or any of its compounds.

(17) Picric acid works, that is to say, works in which nitric acid or a nitrate is used in the manufacture of picric acid.

(18) Paraffin oil works, that is to say, works in which crude shale oil is refined.

(19) Bisulphite works, that is to say, works in which sulphurous acid is used in the manufacture of acid sulphites of the alkalis or alkaline earths.

(20) Tar works, that is to say, works where gas tar or coal tar is distilled or is heated in any manufacturing process.

(21) Zinc works, that is to say, works in which by the application of heat zinc is extracted from the ore, or from any residue containing that metal.

SECOND SCHEDULE.—REPEALS.

SECTION AND CHAPTER	SHORT TITLE.	EXTENT OF REPEAL.
44 & 45 Vict., c. 37.	The Alkali, etc., Works Regulation Act, 1881.	The whole Act.
47 & 48 Vict, c. clvii.	The Local Government Board's Provisional Order Confirmation (Salt Works) Act, 1884.	The whole Act.
55 & 56 Vict., c. 30.	The Alkali, etc, Works Regulation Act, 1892.	The whole Act.

APPENDIX IV.

"WELFARE WORK" OR "PROSPERITY SHARING".

The authors believe that the documents reproduced in the following pages, and the particulars which are there given respecting what has been termed "welfare work" or "prosperity sharing" will be of interest to many manufacturers. They had originally intended to deal with this matter at greater length, as they are of opinion that the experience of those firms who have acted as the pioneers of the movement in this country has proved beyond all question that such machinery for securing efficient and contented workpeople is almost if not quite as important as the ordinary plant and machinery of manufacture. If a second edition of the present work should be called for, they will endeavour to devote such attention to the subject as it clearly merits.

THE CO-PARTNERSHIP SCHEME AT PORT SUNLIGHT.

(By the courtesy of Messrs. Lever Bros., Ltd.)

One thousand and forty-one employees of Lever Brothers, Limited, including directors, managers, salesmen, travellers. advertising managers, clerks, workmen, labourers, and others (male and female alike, there being no sex barrier or distinction), who had qualified under the terms of the Lever Brothers Co-Partnership Scheme, were on July 23, 1909, admitted to co-partnership by the distribution among them of the first issue of Partnership Certificates of the nominal capital value of £113,650.

This was the first distribution of partnership certificates under the scheme formulated by Mr. Lever at the beginning of 1909, and since approved and passed by the shareholders of the company. The scheme contemplates the annual distribution of partnership certificates to all employés of the company

who have reached the age of twenty-five years, and can show a clear record of at least five years' faithful and loyal service. No cash is paid, or financial liability incurred by the employé, and the only obligation devolving on the partner-employés is that they sign a form of application for the certificates, which embodies an undertaking not to waste time, labour, materials or money in the discharge of their duties, but loyally and faithfully to further the interests of Lever Brothers, Limited, its associated companies, and their co-partners, to the best of their skill and ability. This pledge of the applicants is in accordance with the motto of the Partnership Trust, "Waste not, want not".

In each future succeeding year a distribution of partnership certificates is intended to be made for amounts equal in par value to approximately 10 per cent of the annual salary or wages of the employés, to whom they may be continued until the holder has accumulated the maximum amount obtainable in each class according to a scale set out in the Trust Deed. This maximum may equal a nominal amount of from two to four years' total salary or wages of the employé. But the trustees have the discretion to vary the allotments according to the merits of the applicants, the decision of the trustees being subject to an appeal in the first place to a representative committee, and, ultimately, to the holder of the ordinary shares, or in future the majority holders.

As the scheme, however, has been made retrospective by the founder, a goodly number of certificates in the first distribution were for amounts based on the previous one, two, three, four, five, six, seven, or eight years' salary or wages of the employé. It has been decided by Mr. Lever to date the scheme back to the beginning of the present century, so that any present employé who was twenty-five years of age in 1901 and had been five years or over in service at that date, was eligible to receive certificates for eight years.

Of the total number of certificates issued, 303 were retrospective in respect of eight years or over, forty-two for seven years, eighty-one for six, 123 for five, 159 for four, 131 for three, ninety-nine for two, and 103 for one year. In subsequent distributions the partnership certificates will, as stated above, be for amounts representing approximately 10 per cent of the

employé's salary or wages for the previous year; and the Trust Deed provides that in no case shall partnership certificates for a nominal amount exceeding the total of £500,000 be at any one time issued and outstanding, except with the consent in writing of the holder of the ordinary shares, or of the majority of the ordinary shares, in the company.

The phrase "issued and outstanding" is explained by a provision of the Trust Deed securing that the partnership certificates shall be cancelled whenever the holder ceases to be an employé of the company. If he leaves the service of the firm voluntarily from any other cause than age or permanent incapacity caused by ill-health, his partnership certificate will be surrendered. It is also to be cancelled absolutely in case of misconduct, flagrant inefficiency, disloyalty, or breach of the partnership undertaking. On retirement through age or ill-health, or superannuation, the partnership certificates are to be exchangeable, on the terms provided under the trust, for 5 per cent preferential certificates. The widows of registered holders whose partnership certificates are cancelled by death will also receive preferential certificates on the same basis.

In addition to the partnership certificates, preferential certificates have been issued in favour of widows of employés, and in favour of the Divine Service Committee of Christ Church, Port Sunlight—the latter under a provision of the new partnership scheme which enables Mr. Lever, or the future majority holder of the ordinary shares, to require "the allotment of preferential certificates to or for the benefit of any institution, the object of which shall be the advantage, betterment, or enjoyment of persons in the employ of the company, or of the companies associated therewith, including Christ Church of Port Sunlight, the Day or Sunday Schools, clubs, parks, and the granting of scholarships in connection with the children of such persons". By this provision is emphasized the fact that the new partnership scheme is the development and continuation of the system already in existence at Port Sunlight under the name of prosperity-sharing. It has been unaccountably assumed by some commentators on the partnership scheme that it will put a stop to some of the other forms of prosperity-sharing. This is quite erroneous. The previously existing benefits to employés will not be affected except in the advantageous way of additional

endowment under the provision of the Trust Deed just mentioned. The contributions of the firm to the Old Age Pension Fund, the Holiday Fund, the provision of trains and tramway cars for the girl-workers not living in the village, the maintenance of baths, rest-rooms, cottage hospital, gymnasium, clubs, and other provision for the health and welfare of the staff, the payment of continuation school fees, etc., will continue as before. There will be no deduction of any kind from either wages or existing privileges of the workpeople. "The advantage of persons in the employ of the company" is the object of the new scheme as declared in the Trust Deed, but with the intention, always insisted upon by the founder, of increasing the success of the business, of creating the further prosperity in which the workers are to share, above all of increasing the happiness in business of all the workers, and promoting industrial welfare and efficiency by the closer relationship of capital, management, and labour.

The partnership and preferential certificates will rank for dividend at the next annual distribution of profits in the following manner. The dividends of the preference shareholders of the company having been paid, the holders of the ordinary shares will take 5 per cent on their capital. The preferential certificates will rank for payment of a 5 per cent dividend. When this is paid the remaining profits will be shared *pro rata* between the ordinary shares and the partnership certificates.

It will be seen that this is not a profit-sharing scheme in the ordinary acceptance of that term, and it is hoped that by this plan of co-partnership the obstacles to success of so many profit-sharing schemes will be overcome. According to Government labour statistics, which were published last year, out of 193 profit-sharing schemes started in this country between 1865 and 1895 only fifty-one were known to survive in 1907. By the provisions of the Lever Brothers' Co-partnership Trust the employés have a gradually accumulating interest, represented by partnership certificates, in the prosperity of the business undertaking, and in accordance therewith they will share with the shareholders in any fluctuation of prosperity, thus suffering loss of dividends, and the consequent depreciated value of their holdings, proportionately with the ordinary shareholders, but without being called upon to make any cash sacrifice out of their salary

or wages to make good losses, or to incur any financial liability which they would not be in a position to undertake. The scheme does not introduce any confusion between the functions of management and labour. The interest of the workers cannot be alienated, as their certificates cannot be bought or sold or mortgaged. Their dividends are absolutely their own, free from all control of the management. They may be used to acquire further interest in the company by investment in the preference shares, or put to any other use at the absolute discretion of the holders. The benefits conferred by the certificates cannot be varied except by consent of a three-fourths majority of the holders. Although it is of the essence of the scheme that the partnership certificates themselves shall cease with employment and shall not be transferable or heritable, their exchangeability for preferential certificates to the holder in case of retirement, or to the widow in case of death, insures a substantial addition to old-age pension, and to provision for widowhood. As regards the children, the partnership certificate holder is naturally in a better position to provide for them, and besides the educational and social advantages enjoyed by the children living at Port Sunlight, "this business" (Mr. Lever has said to the employés) "is open for your children to enter. They can come into the business if they wish to be associated with it, and provided there is a vacancy for them, and earn their own partnership certificates in the same way as their fathers have done before them."

BOURNVILLE WORKS SUGGESTION SCHEME.—MEN'S DEPARTMENTS.

(Particulars of this scheme are given here by the courtesy of Messrs. Cadbury Bros., Ltd.)

The suggestion scheme has been introduced at Bournville with the object of encouraging our employés to make suggestions concerning the welfare either of the business or themselves. From the very commencement of the scheme we have been desirous that all at Bournville should take an active interest in everything around them. Suggestions are invited on any question connected with the efficient working of the business, and the following will indicate on what lines they may be made :—

(1) Improvement in goods :—
  (a) New goods.
  (b) Improved quality.
  (c) Improved appearance, either of goods or their wrappings.
(2) Improvement in method of manufacture :—
  (a) Cheaper methods of manufacture, including the saving of material or a reduction of the labour cost.
  (b) Hygiene. Improvements which affect cleanliness in the methods of production, or in the health, comfort, or safety of those engaged in manufacturing processes.

(3) Suggestions appertaining to advertisements or methods likely to increase sales.

(4) Suggestions affecting our social well-being—athletic and other clubs, societies, libraries, magazine, etc.

(5) Any suggestions of whatever character, so long as they bear some relation to, or are connected with, the works at Bournville. Awards ranging in value from 5s. upwards are made twice yearly, at midsummer and Christmas, for suggestions meriting reward.

Suggestion boxes are fixed in convenient places in nearly all the departments, also in dining-room, lodge, youths' club, and pavilion, upon which will be found suggestion books. All communications should be made by means of these books, the suggestion written on, or attached to, the form and dropped into the box. In case of drawings, etc., send them to the works foreman's office. It is imperative that all particulars at the head of form, which bears a distinctive number, should be carefully filled in. Forms may be taken from the book and filled in at home. These are acknowledged by a weekly notice posted on the boards, giving a list of the numbers of suggestions received for consideration. Should any number not appear on this list a communication should at once be sent to the works foreman.

Those who have left the employ of the firm are entitled to prizes for any suggestions made whilst they were here, unless they should leave through misconduct.

When a suggestion is received it is sent to the member of the committee under whose scope it may come for a report, and in no case is the name of the suggester divulged, except in

special cases by the consent of the committee. A suggester may interview a member of the committee to further explain his ideas by stating his desire to do so on the suggestion form.

Suggestions are considered by the Works Committee, which is composed of a director, with representatives of the offices and works, and two representatives appointed by the foreman.

In awarding prizes every effort is made by the committee to give each suggestion full consideration, and no prize is awarded unless the suggestion has been actually carried out and found practicable The final judging lists are placed before the firm for approval.

A complete record of all the suggestions made by each employé, whether accepted or declined, is kept, together with prizes awarded.

Suggesters should not lose sight of the fact that the greatest good which they accomplish by making these suggestions is not alone their pecuniary value to the firm, or the monetary prize awarded. The real achievement is the development of mental and creative power which makes them more valuable and useful workmen.

All suggestions, ideas, etc., are regarded as confidential and are the property of the firm.

Any information required regarding suggestions can be obtained from the works foreman's office.

EDUCATION.

Messrs. Joseph Crosfield & Sons, of Warrington, have done much in the way of securing model conditions of labour for their workpeople. The following particulars are of interest:—

It is a condition of employment that all young persons employed by the firm must have passed the Sixth Standard at a day school. Also, that all young persons shall attend evening school (at the firm's expense when specified conditions are complied with).

Prizes are offered for conduct, progress, and attendance at the evening schools, particulars of which are as follows:—

Scheme for Remission of Fees and Payment of Cash Prizes.

Conditions.—All fees of the Branch Technical Schools for the session must be paid on or before 30th November next.

The fees at the Commercial Institute of either 3s. or 7s. 6d. for the session according to the course taken, and the fee at the Central Technical Institute of 7s. 6d. have always been payable in advance, and will continue to be so.

The student must make at least 85 per cent. of possible attendances, and must sit for the examination at the end of the session.

Students will attend the schools under which their names appear, and will not be allowed to go to any other without special permission from the Works General Office. This does not apply to those students who have qualified for admission to the Central Technical Institute.

Subject to the above rules, fees will be refunded and the following cash prizes will be given:—

Fees —For 85 per cent attendances, fee only; between 90 per cent and 94 per cent, inclusive fee, plus 1s.; between 95 per cent and 99 per cent, inclusive fee, plus 1s. 6d; for 100 per cent attendances, fee, plus 2s. 6d.

Prize for Progress: Branch Technical Schools.—If remarks are very satisfactory, 3s. 6d.; if remarks are satisfactory, 3s. *Central Technical Institute.*—If remarks are very satisfactory, 8s.; if remarks are satisfactory, 7s. 6d.

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Brass Band.

The firm supports a Brass Band consisting of twenty-six workmen. Each member is provided with uniform and instrument free, and the firm also pays for a professional instructor. Two or three practices are held per week. During the season prizes were won to the value of £350 13s., including eleven first prizes, which was the greatest number won by any one band. In addition to numerous contests, the band attends social functions when required.

Swimming.

All boys and girls in the offices or the works, during the sixteenth year of their age, are taught to swim. Two squads of boys go each week during working hours to the Corporation Baths in charge of an instructor from the works. The girls go

each week in one squad, and are taught by an instructress from the baths. The time lost, and the cost of the baths and instruction, are borne by the firm. The courses last from June to September, and consist of about thirteen lessons.

Dining Arrangements.

Dining accommodation is provided for all employés, male and female.

The men's dining hall measures 111 feet by 52 feet. The kitchen, which was opened in 1907, is fitted with modern cooking apparatus. Meals are cooked for the workpeople, and served at 4d. per head.

Education of Junior Employés at Cadbury Brothers, Limited, Bournville Works.

Classes of various kinds have been held at the works for upwards of eight years. In the summer of 1906 the whole of the educational work was centralized, and the Bournville Works Education Committee was formed to assist the firm in their endeavours to forward the welfare of the employés in this direction. The work of this committee is to arrange for compulsory attendance at evening classes by all employés under 16 years of age, and to encourage attendance by the older ones; also to negotiate with local educational bodies as to proper facilities at the various schools in the district, the education of the juniors at the evening continuation schools being on broad general lines leading up to more specialized instruction at the Technical Schools. The number of employés attending compulsorily (all under 16 years of age) is as follows:—

1906-7	430
1907-8	542
1908-9	538

The number attending voluntarily (between 16 and 19 years of age) :—

1906-7	156
1907-8	305
1908-9	264

All these classes are held at the local schools, and are under the jurisdiction of the local education authority.

The compulsory students attend during the winter months only, on two evenings a week, for two hours per evening.

Fees up to 7s. 6d. are returned by the firm to all students up to 19 years of age, with reference to whom the head master's report *re* attendance, progress, and conduct is satisfactory.

Employés up to 16 years of age are also required to attend twice a week at the physical training classes, held at the works during work hours, gymnastics once and swimming once.

The juniors who attend classes compulsorily participate in a general reward scheme, the rewards (first, 12s. 6d.; second, 10s.; third, 7s. 6d.) being based on reports from: (1) Works Department, (2) Evening Continuation School, (3) Works Physical Training Classes.

In order to provide classes during the day and evening in gymnastics and swimming, a body of managers was formed, who regulate the work of the instructors and act generally under the Board of Education. This body receives grants from the Board of Education and a subscription from the company.

These classes are termed the Bournville Works Classes, and, as the name indicates, are all held at the works. They are as follows:—

(1) Junior Boys' and Girls' Gymnastic and Swimming Classes, held in the daytime.

(2) Men's and Girls' Evening Gymnastic and Swimming Classes.

(3) Men's and Girls' Ambulance Classes.

(4) Girls' Gardening Class

(5) Men's and Boys' Boot Repairing Classes.

The total number of individual students attending these classes during session 1906-7 was 1049. Some attended two or three classes.

No deduction is made from the wages of the juniors who attend the day classes (No. 1). The firm are of the opinion that the renewed energy resultant upon the attendance at these classes fully repays them for the time lost by the boys, who are paid by the day, the same principle being recognized in connection with the attendance at the day classes by the junior girls, the majority of whom are pieceworkers.

Extension of the Bournville Works Educational Scheme.

(*Extract from "The Bournville Works Magazine," May*, 1909)

The firm, with the cordial and unanimous approval of the heads of the various departments, with whom a special conference was held on this question in the autumn of last year, have now decided that all boys shall attend evening classes up to the age of 18. For the girls, it is recognized that the majority leave the works after a few years to look after homes of their own. It has been decided that the girls also shall attend up to the age of 18, and that their training shall include a thorough instruction in housewifery. Such subjects as English literature and physical training will, it is hoped, also occupy prominent places.

While boys who are engaged for the factory side of the works at the age of 14 will be admitted on the condition that they have worked in the higher standards and have good reports from the elementary school head master, boys of the same age who are engaged for the offices will be required to have worked in the ex-seventh standard, and will also have to pass an examination set at the works. Those from secondary schools who do not leave until they are 16 years of age may be engaged for the offices, or for the trades in the factory, on condition that they pass the necessary tests. These boys will be at liberty to commence attendance at the more advanced classes immediately.

The system proposed is roughly as follows: All boys who enter the works at the age of 14 will be required to do unskilled work until they reach the age of 16, and, whilst doing so, will be required to attend evening continuation school and physical training classes as at present. At the end of that time the most suitable boys will be transferred to skilled work to which they are specially suited, and, if found satisfactory at the end of a probationary period, will be asked to enter into an agreement. The transfer will depend upon the boy's health, his expressed wish to learn a particular trade, his parent's consent, and satisfactory reports from his foreman and the evening school head master.

This system of choosing apprentices has been decided upon after much deliberation. It is felt that a boy at 14 years of age hardly knows what trade he would like to learn. He knows so little about the industrial world that, if apprenticed at that age to any trade, he may in a year or two think that he would have been much wiser to have started in some other line. It is generally agreed that promotion should depend not on favour, but on merit, and merit alone, and the firm will be able to choose, after two years' personal experience, boys who through hard work and constant application to education, are best fitted for the various trades.

The boys transferred will be expected to attend such classes as are approved by the Works Education Committee until the end of their apprenticeship, which will as a rule extend up to the age of 21. They will be paid at a lower rate of wages than those not learning a trade, but the deduction will be returned in some cases in the form of tools, and in others in such form as may hereafter be determined

The apprenticeship system is practically dead. With the development of the factory system, and with the growth of industrial specialization, the all-round training given to the old apprentices is less necessary—both from the point of view of the employer and the worker. But while the economy of specialization has been in view, the wider economy that is in a broad training has been overlooked. It is the value of this which the new apprenticeship scheme has recognized. The purpose is to teach the workers all that is possible, so that in every department all will have the opportunity of becoming specially equipped in the class of work in which they are engaged, while those in the trade sections will receive an unusually wide training, owing to the great variety of work undertaken at Bournville.

The most suitable workers, whether apprenticed or not, will be given the opportunity of attending day classes, and, in special cases, a university or working men's college for a course of subjects. For both boys and girls up to sixteen years of age the education given at the evening continuation schools is on broad lines, but after that age the boys apprenticed will specialize, but not narrowly. The remainder will continue on broad general lines.

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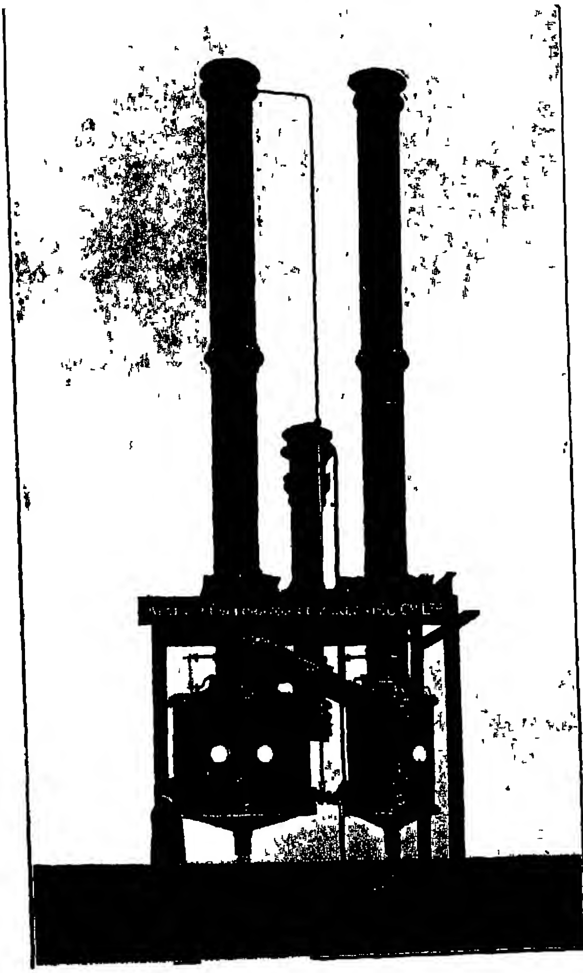

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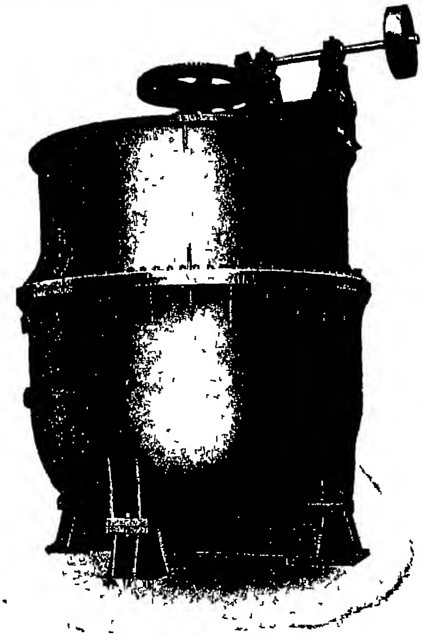

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